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BIOLOGICAL SCIENCES

STUDY OF HERPESVIRUSES IN CELL CULTURE AND MECHANISM OF INFECTION IN MODERN RESEARCH

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Abstract

Herpesviruses (family *Herpesviridae*) are widespread double-stranded DNA viruses capable of establishing lifelong latent infections and causing diverse clinical manifestations, particularly in immunocompromised individuals. In addition to acute and recurrent infections, certain herpesviruses such as Epstein–Barr virus (EBV) and Kaposi's sarcoma–associated herpesvirus (KSHV) possess oncogenic potential, making them a major focus of modern virological and oncological research. This study provides a comprehensive overview of herpesvirus biology, replication mechanisms, latency, and pathogenesis, with a particular emphasis on in vitro cell culture models and emerging molecular technologies. Various cell lines, including Vero, HEp-2, HeLa, HFF, and L929 fibroblast cells, are discussed as experimental platforms for studying herpesvirus infection, cytopathic effects, and antiviral susceptibility. Experimental findings from L929 fibroblast cells inoculated with HSV-2 demonstrate characteristic stages of cytopathic effects, highlighting the suitability of cell culture systems for visualizing viral replication dynamics. The article also reviews current diagnostic approaches, including PCR-based molecular methods, serological assays, and immunohistochemical techniques, which are critical for detecting both active and latent infections. Furthermore, the potential of CRISPR-Cas9 technology as a novel antiviral strategy targeting latent herpesvirus genomes is critically evaluated. Although conventional antiviral therapies effectively suppress viral replication, they fail to eliminate latent infection. CRISPR-based genome editing offers a promising avenue for achieving functional cure, despite existing technical and bioethical challenges. Overall, this study emphasizes the importance of integrating cell culture models, molecular diagnostics, and advanced genetic technologies to improve the understanding, diagnosis, and treatment of herpesvirus infections.

Keywords: Herpesviruses, latent infection, CRISPR-Cas9, cell culture, viral replication, molecular diagnostics, antiviral treatment.

Introduction:

Herpesviruses (family Herpesviridae) are large-genome, double-stranded DNA viruses widely distributed in humans and animals. They are of special importance in virology because they are distinguished by their ability to reactivate latency and produce different clinical manifestations. Herpesviruses can remain latent in the cells of the body, creating lifelong infections. These viruses are acute infections that damage various organ systems. When the immune system is weakened, they have the ability to cause severe complications [1]. Herpesviruses not only cause infection, some types (eg, EBV and KSHV) can cause oncogenic transformation in humans [2]. In this regard, herpesviruses are not only infectious, but also the subject of oncological research. The spread of herpesviruses at the global level and the social and economic impact of the diseases caused by them increase the relevance of the research conducted in the direction of the pathogenesis and treatment of these viruses [3]. Herpesviridae family represents a large and complex group in virological taxonomy. Viruses included in this family are divided into three main families:

1) Alphaherpesvirinae 2) Betaherpesvirinae 3) Gammaherpesvirinae [4].

Alphaherpesvirinae: This group includes Herpes simplex virus 1 (HSV-1), Herpes simplex virus 2 (HSV-2), and Varicella-zoster virus (VZV). These viruses are characterized by fast replication and mainly create latency in nervous tissues. HSV-1 mainly causes oral and labial lesions, while HSV-2 causes genital herpes. VZV is the causative agent of chicken pox and shingles [5]. Betaherpesvirinae: This group includes Cytomegalovirus (CMV), Human herpesvirus 6 (HHV-6), and Human herpesvirus 7 (HHV-7). These viruses replicate slowly in cell culture and remain mostly latent

in immune cells. CMV can cause severe infections in those with weakened immune systems (eg, post-transplant or HIV patients) [6]. Gammaherpesvirinae: Epstein-Barr virus (EBV) and Kaposi's sarcoma-associated herpesvirus (KSHV, HHV-8) are included in this group. Gammaherpesviruses show a tropism mainly to lymphoid cells and create long-term latency. EBV is the main etiological factor of infectious mononucleosis and some lymphomas, and KSHV is the main etiological factor of Kaposi's sarcoma [7]. Genomes of herpesviruses consist of double-stranded DNA and range in size from 120–240 kbp. The genome contains a variety of structural and regulatory genes and encodes more than 70 proteins. These proteins play an important role in virus replication, synthesis of structural components, evasion of the body's immune response, and latency mechanisms [8]. Viruses pass through the cell wall membrane and replicate in the cell nucleus. The mechanism of infection and pathogenesis of herpesviruses is based on the type of virus, the site of infection and the immune state of the body. Infection can occur in different ways: skin and mucous membrane contact (HSV-1, HSV-2, VZV), oral, airborne or sexual (EBV, CMV); Transplantation or transplacental infection (CMV);

The virus initially enters epithelial cells, where rapid replication begins. Alphaherpesviruses enter the transmission nerves and reach the nerve ganglia by retrograde flow, where they take a latent state. For example, HSV may remain latent in the trigeminal or sacral ganglia, and VZV may remain latent in the dorsal root ganglia. During the latency period, the viral genome remains in the cell nucleus in an episomal form and does not show any clinical symptoms. Due to the weakening of the immune system or the influence of factors such as stress, infection, UV radiation, the virus is activated and may manifest itself with symptoms at the site of the previous infection or in new areas [9]. Betaherpesviruses maintain latency mainly in monocytes and lymphocytes, while gammaherpesviruses can remain latent in B-lymphocytes. The pathogenesis of herpesviruses is not limited to cell lysis and inflammatory reactions. Some herpesviruses can also cause the formation of tumor cells by manipulating genes that play an important role in regulating the cell cycle. For example, EBV can lead to Hodgkin and non-Hodgkin lymphomas by causing B-cell immortalization. KSHV is the etiological factor of Kaposi's sarcoma and some rare lymphoproliferative diseases [10].

Clinical signs of herpesviruses are diverse and vary depending on the type of virus, the body's immune system, and the location of the infection.

HSV-1 and HSV-2: HSV-1 causes infections involving the mouth, lips, eyes, and brain. The most common form is labial herpes (cold sore). HSV-2 is the main cause of genital herpes and is sexually transmitted. It can also cause neonatal herpes in newborns [11].

VZV (Varicella-Zoster Virus): Primary infection presents as chicken pox (varicella). During reactivation, shingles (herpes zoster) appear - this manifests as a painful, blistering rash along the nerve [12, 13].

CMV (Cytomegalovirus): Is asymptomatic in those with a healthy immune system, but can sometimes present with mononucleosis-like symptoms. In immunosuppressive patients, it can cause severe pneumonia, retinitis, hepatitis and brain pathologies. If transferred to the fetus during pregnancy, it can cause severe abnormalities before or after birth [14].

EBV (Epstein-Barr Virus): It is the main causative agent of infectious mononucleosis ("kissing disease"). It has oncogenic potential during long-term latency: Burkitt's lymphoma, nasopharyngeal carcinoma, etc. [15].

KSHV (Kaposi Sarcoma Herpesvirus): Can cause Kaposi's sarcoma, primary effusion lymphoma, and Multicentric Castleman's disease in immunocompromised individuals (especially AIDS patients) [16].

Diagnosis of herpesviruses is determined by several methods. These include -Virus isolation and cell culture, PCR and real-time PCR - provide high accuracy in the detection of viral DNA, Serological tests (ELISA, Western blot) - determine the phase of infection by detecting antibodies, Immunohistochemistry and in situ hybridization - used to detect viral antigens and genome in tissues [17].

The main goal in the treatment of herpesvirus infections is to stop the replication of the virus, relieve symptoms and prevent reactivation. The main antiviral drugs currently used against herpesviruses target the DNA polymerase enzyme of the virus [18].

In recent years, it has become possible to target specific regions of the herpesvirus genome with CRISPR-Cas9 technology. This is a promising approach for complete eradication of latent infection [19]. At the same time, work is being done in the direction of delivery of antiviral drugs, immunotherapy and antiviral vaccines with nanoparticles. Currently, only an effective vaccine against VZV is available. Extensive research is being done on the development of vaccines against other herpesviruses.

Varicella vaccine (Varivax): -Used to prevent chicken pox infection in children. Live attenuated virus based. Zoster vaccine (Shingrix, Zostavax): Used to prevent shingles in the elderly. Shingrix is a recombinant non-enveloped protein-based vaccine that is more effective and less risky [20]. Vaccination against HSV-2: Vaccines in Phase III clinical trials, especially vaccines based on the gD2 antigen, show promising results in generating an immune response [21].

CMV vaccine: Research is being done on vaccines containing different antigens that have a synergistic effect. It is critical for pregnant women and transplant patients. The development of effective vaccines is complicated by the latent capacity of herpesviruses and their immune evasion strategies. In the future, the introduction of vaccines based on mRNA technology may be a turning point in this field. In vitro cell culture is the main experimental platform for the study of herpesvirus biology, pathogenesis, and antiviral therapies. This method is widely used to analyze viral replication mechanisms, evaluate the effectiveness of antiviral drugs, and test new vaccine designs. Advantages of cell culture: It is possible to visualize the stages of the viral replication cycle. The degree of resistance of viruses to antiviral drugs can be measured. Mutant forms of viruses can be studied by genetic modification. Latent infection models are difficult to establish. The complexity of the immune system cannot be fully replicated in

cell culture. Some types of herpesviruses are activated only in certain cell types (eg B-lymphocytes for EBV). For this reason, 3D organelle models and mouse models have recently been used as complementary tools in laboratory research [22].

Cell culture is a method of growing cells in the laboratory, used in various research and experiments. In this process, cells are grown and propagated in a special nutrient medium [23].

For the study of herpesviruses in laboratory conditions, their reproduction in appropriate cell culture is one of the main research methods. Because herpesviruses have a broad cell tropism, they can be grown successfully in a number of cell lines. The cell lines used are: Vero cells (African green monkey kidney cells): Widely used to study HSV-1 and HSV-2. HEp-2 and HeLa cells: Epithelial cells of human origin, suitable for observation of cytopathic effects.

HFF (Human Foreskin Fibroblasts): Optimal for herpesviruses such as CMV and HHV-6. ARPE-19 and RPE-1: Retinal pigment epithelial cells are used to investigate ocular types of CMV and HSV [24].

For this purpose, cell lines such as Vero, HEp-2, HeLa, MRC-5 are widely used [25].

Materials and Methods

Materials obtained in our laboratory:

The L929 fibroblast cell line was obtained from a cryo bank. Cells were maintained in pre-prepared nutrient media: DMEM-10% FBS and supplemented with RPIM-10% FBS. Passage process was performed after rapid proliferation of cells was observed. During passaging, cells were detached with trypsin and transferred to new flasks. A part of the passaged cells was filled in cryotubes and frozen for future studies. During the freezing process, 10% DMSO was added to the nutrient medium. Cells were first stored at -80°C, then placed in a liquid nitrogen tank for long-term preservation. Virus inoculation: HSV-2 IgM positive serum obtained from a clinical laboratory was subjected to high-speed centrifugation (16000 rpm) and inoculated into L929 fibroblast cells. Morphological changes in the cells were observed under a microscope.

Changes observed as a result of HSV-2 inoculation:

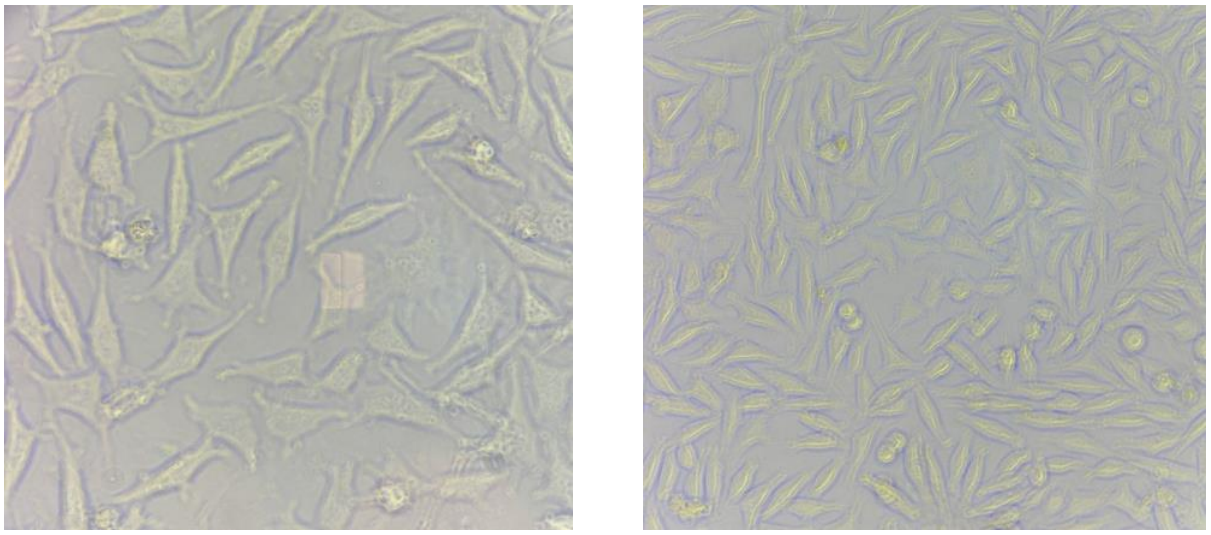
L929 fibroblast cells were observed daily after inoculation with HSV-2. Morphological changes were recorded in the following sequence:

Early stage: Cells were in normal fibroblast morphology and maintained their needle shape. No pathological changes were recorded at this stage.

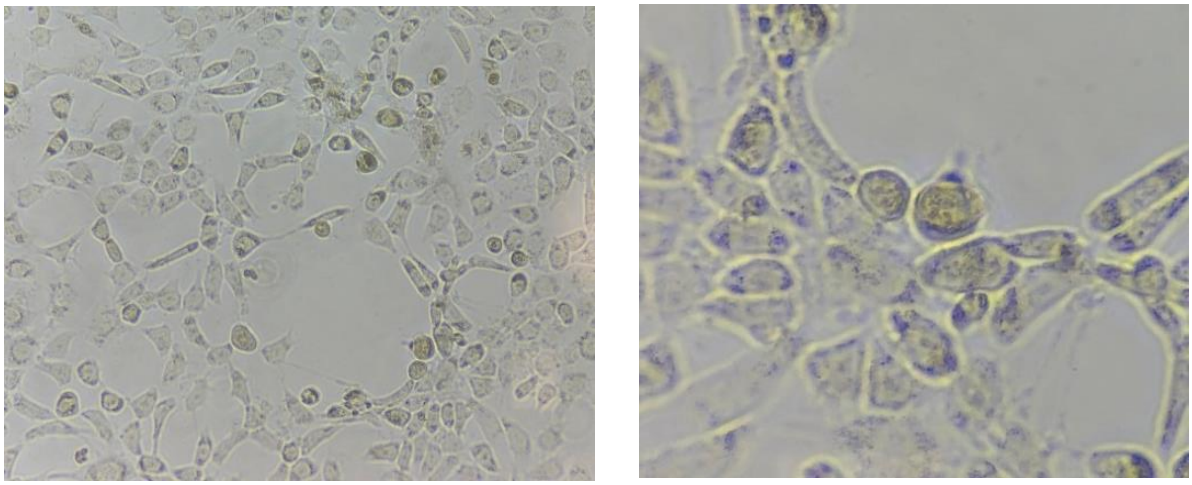
Initial cytopathic effect: Aggregation and round formation of cells were observed. The cells came close to each other and formed small clusters. This stage marked the beginning of cell-to-cell transmission of HSV-2.

Middle stage: The morphology of the cells has changed dramatically. They became round and swollen, the cytoplasm became transparent, and the cells stuck together to form large clusters. Cells that lost contact with the substrate were observed as floating cells. These changes reflected intensive reproduction of the virus and disruption of cell membrane structures.

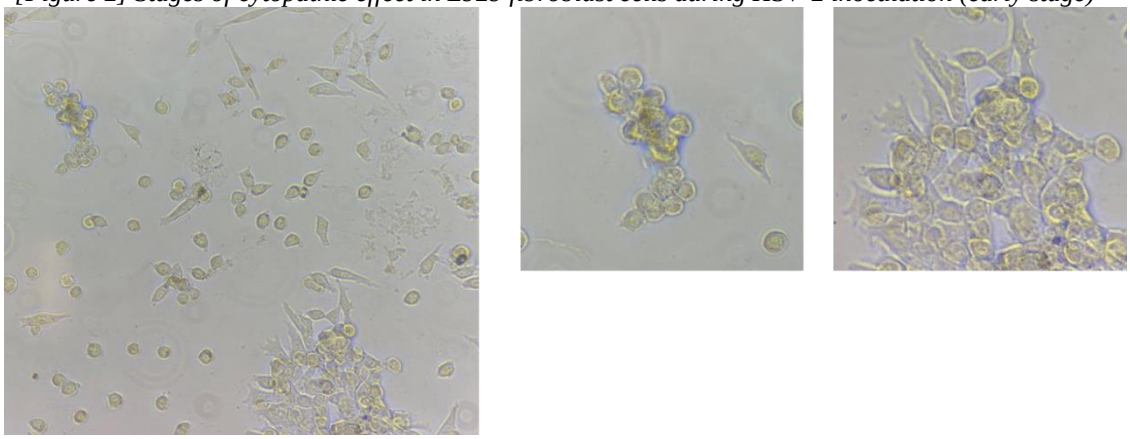
The last stage: The membrane of the cells completely collapsed and the process of fragmentation was observed. This phase was considered the terminal phase of the cytopathic effect. As a result, the majority of L929 fibroblast cells consisted of dead cells.



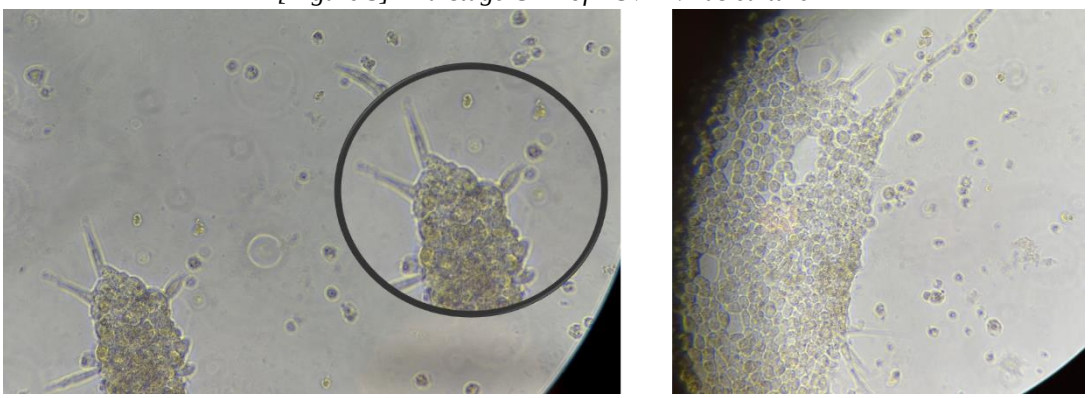
[Figure 1] L929 fibroblast cells microscopic view



[Figure 2] Stages of cytopathic effect in L929 fibroblast cells during HSV-2 inoculation (early stage)



[Figure 3] Mid-stage CPE of HSV-2 virus culture



[Figure 4] Final stage of CPE of HSV-2 virus culture

Cytopathic effects (CPE) caused by herpesviruses in cells are observed under a microscope. These include changes in cell morphology, the formation of syncytiums (the fusion of several cell cytoplasms to form a multinucleated structure), and cell lysis. These symptoms are one of the main indicators of the presence and intensity of infection. After the incubation period, the presence and quantity of the virus is determined by various methods. Plaque assay, $TCID_{50}$ (50% tissue culture infection dose), Immunofluorescence, PCR analysis are included [26, 27]. Application of CRISPR-Cas Technology Against Herpesviruses - The fact that herpesviruses create a latent infection and do not respond to conventional antiviral treatment in this case makes CRISPR-Cas9 technology promising in this field. With this technology, the replication or latent form of the virus can be disabled by targeting specific regions of the viral genome. The main directions of application are as follows:

Cleavage of the latent viral genome: The latent form of HSV-1 and CMV can be eliminated by cutting from the genome using CRISPR-Cas9 [28]. Inactivation of viral genes: Viral activity is reduced by targeting key replication genes such as UL29, UL30 (HSV) and IE genes (CMV). Enhancement of the immune response: Genes that enhance the immune response can be activated in cells through the CRISPR-system. Changes can occur in unwanted regions of the genome. Mechanisms of viral resistance to the Cas system: Eva-

sion of CRISPR targets is possible as a result of mutations. Effective delivery system: AAV vectors and nanoparticle-based systems are currently under testing [29]. Despite all these reasons, the CRISPR-Cas system is considered one of the most promising technologies for the complete elimination of herpesviruses. Research conducted in recent years provides a deeper understanding of viral replication mechanisms, molecular basis of latent infection, and interactions with the immune system. Cell culture, molecular analysis and new genetic technologies, especially the CRISPR-Cas9 system, have opened up new opportunities in the fight against herpesviruses. However, it is still not possible to completely eliminate the latent form of herpesviruses. Currently used antiviral drugs mainly target the replication phase and are ineffective against latent infection. In the future, the use of technologies such as CRISPR-Cas to target viral genomes may revolutionize this field. Also, it is important to conduct more research on immune evasion mechanisms, genetic variations and drug resistance of viruses [30]. The results of these studies will play a key role in the development of both diagnostic and new antiviral strategies. In recent years, the CRISPR-Cas system, considered a revolutionary technology in the field of genetic engineering, has shown promising results in the study and treatment of many viral infections, including herpesviruses. This system enables genetic modification by recognizing and cutting specific DNA sequences in a targeted manner [31].

CRISPR-Cas technology makes it possible to completely destroy or prevent the activation of herpesviruses by targeting the genome of latently hidden herpesviruses in the cell. This is especially relevant for Herpes Simplex Virus 1 and 2 (HSV-1 and HSV-2), Cytomegalovirus (CMV) and Epstein-Barr Virus (EBV) [32].

Because infections caused by herpesviruses have a wide clinical spectrum, accurate and rapid diagnosis is important. Molecular diagnostic methods are considered the most reliable approach to detect the presence of the virus, especially in latent or asymptomatic cases. Among these methods, the polymerase chain reaction (PCR) takes the main place [33].

PCR (Polymerase Chain Reaction)-PCR amplifies the genomic material of herpesviruses, allowing detection of even very low amounts of the virus. This method is used for the identification of viruses such as: HSV-1, HSV-2, CMV, EBV, HHV-6/7, VZV. Applied in both qualitative and quantitative (real-time PCR) formats, PCR-based technologies also allow determining virus genotypes and detecting drug resistance [34].

Conclusion and discussion

Herpesviruses are viruses that are widespread, manifest themselves with different clinical signs and cause lifelong latent infections. Viruses such as HSV-1, HSV-2, VZV, CMV, EBV, HHV-6, HHV-7, and HHV-8 pose serious risks to human health, especially in immunocompromised individuals and can cause complications and sometimes oncogenic consequences [35]. As can be seen from the data presented in the article, the study of herpesviruses requires a multidisciplinary approach. The genetic structure of viruses, replication mechanisms, latency strategies, and interactions between the body and the immune system should be thoroughly investigated. In recent years, advances in molecular biology, cell culture, CRISPR-Cas technology, molecular diagnostics, and vaccine research have led to a better understanding of herpesviruses and the development of targeted approaches [36–37].

Although the CRISPR-Cas system offers a promising approach for targeting latent forms of herpesviruses and removing them from the genome, the clinical application of this technology is still at an early stage, and bioethical, technical, and safety issues still require serious investigation [38].

New technologies—particularly mRNA, CRISPR, and NGS—may enable the development of more specific, effective, and personalized approaches to herpesviruses. Future studies should focus on viral latency mechanisms, mutational profiles and immune evasion strategies.

References:

1. Whitley RJ, Roizman B. Herpes simplex virus infections. *Lancet*. 2001;357(9267):1513–1518.

2. Cesarman E. Kaposi sarcoma–associated herpesvirus: pathogenesis and treatment. *J Clin Invest*. 2016;126(9):3165–3175.

3. Looker KJ, Magaret AS, Turner KM, et al. Global estimates of prevalent and incident HSV-2 infection. *PLoS One*. 2015;10(1): e0114989.

4. Pellet PE, Roizman B. The family *Herpesviridae*: a brief introduction. In: *Fields Virology*. 6th ed. 2013. p. 1802–1822.

5. Arvin AM, Gilden D. Varicella-zoster virus. *Clin Microbiol Rev*. 2013;26(4):728–743.

6. Cheeran MCJ, Lokensgard JR, Schleiss MR. Neuropathogenesis of congenital CMV infection. *Clin Microbiol Rev*. 2009;22(1):99–126.

7. Kenney SC, Mertz JE. Regulation of the latent–lytic switch in Epstein–Barr virus. *Semin Cancer Biol*. 2014; 26:60–68.

8. Roizman B, Knipe DM. Herpes simplex viruses and their replication. In: *Fields Virology*. 6th ed. 2013. p. 1823–1897.

9. Komatsu T, Nagata K, Wodarz D, et al. Herpesvirus latency and host immune response. *Curr Opin Virol*. 2017; 23:56–61.

10. Gantt S, Casper C. HHV-8–associated neoplasms. *Curr Opin Infect Dis*. 2011;24(4):295–301.

11. James SH, Kimberlin DW. Neonatal herpes simplex virus infection. *Infect Dis Clin North Am*. 2015;29(3):391–400.

12. Gershon AA, Breuer J, Cohen JI, et al. Varicella zoster virus infection. *Nat Rev Dis Primers*. 2015; 1:15016.

13. Gilden D, Nagel MA, Cohrs RJ, et al. Varicella zoster virus in the nervous system. *F1000Research*. 2015; 4:1356.

14. Pass RF. Cytomegalovirus. In: *Remington and Klein's Infectious Diseases of the Fetus and Newborn Infant*. 7th ed. 2011.

15. Kang M, Li Y, Zhao Y, et al. EBV-associated gastric carcinoma. *Cancer Lett*. 2019; 461:237–246.

16. Ablashi DV, Salahuddin SZ, Josephs SF, et al. HHV-6 associated lymphoproliferative disorders. *JAMA*. 1988;260(19):3144–3148.

17. Li Q, Ding X, Lin A, Liu Y. Diagnosis and therapy of CMV infection. *Virol Sin*. 2020;35(2):172–179.

18. Whitley RJ. Antiviral therapy of herpesvirus infections. *Antiviral Res*. 2006;71(2–3):134–145.

19. van Diemen FR, Kruse EM, Hooykaas MJG, et al. CRISPR-Cas9 antiviral immunity. *Nat Microbiol*. 2016; 1:16004.

20. Cunningham AL, Lal H, Kovac M, et al. Herpes zoster subunit vaccine efficacy. *N Engl J Med*. 2016; 375:1019–1032.

21. Belshe RB, Leone PA, Bernstein DI, et al. HSV vaccine trial. *N Engl J Med*. 2012;366(1):34–43.

22. Watanabe T, Bareno G, Kawai Y, et al. 3D organoids for herpesvirus infection. *Nat Biomed Eng*. 2021;5(9):876–889.

23. Freshney RI. *Culture of Animal Cells*. 7th ed. Wiley; 2016.

24. Wang Y, Su C, Yin X, et al. HSV-1 infection of Vero cells. *Virol J*. 2020; 17:22.

25. Smith JS, Robinson NJ. Global HSV prevalence. *J Infect Dis*. 2002;186(Suppl 1): S3–S28.

26. Freshney RI. Subculture and cryopreservation of cells. *Methods Mol Biol*. 2010; 731:1–18.

27. Roehm PC, Shekarabi M, Wollebo HS, et al. CRISPR inhibition of HSV-1. *Gene Ther*. 2016;23(7):540–546.

28. Corey L, Wald A. Genital herpes. In: *Sexually Transmitted Diseases*. 4th ed. 2008.

29. Smith KO, Kennell WL. CPE in viral infections. *J Virol Methods*. 1981;2(4):219–226.

30. Flint SJ, Enquist LW, Racaniello VR, Skalka AM. *Principles of Virology*. 4th ed. ASM Press; 2015.

31. Hierholzer JC, Killington RA. Virus isolation and quantitation. In: *Virology Methods Manual*. 1996.

32. Xu X, Wan Y, Hu P, et al. CRISPR/Cas9 against latent herpesviruses. *Trends Microbiol*. 2022;30(4):284–296.

33. Joung J, Konermann S, Gootenberg JS, et al. Genome-scale CRISPR screening. *Nat Protoc*. 2017;12(4):828–863.

34. Collins-McMillen D, Buehler J, Peppenelli M, Goodrum F. CMV latency regulation. *Viruses*. 2018;10(8):444.

35. Doudna JA, Charpentier E. CRISPR-Cas9 genome editing. *Science*. 2014;346(6213):1258096.

36. Ehrlich ES, Yu X, Ragheb JA. HSV latency regulation. *PLoS Pathog*. 2020;16(3): e1008366.

37. Mackay IM. Real-time PCR in virology. *Nucleic Acids Res*. 2004;32(4):1292–1305.

38. Johnston C, Gottlieb SL, Wald A. HSV vaccine development status. *Vaccine*. 2016;34(26):2948–2952.

ECONOMIC SCIENCES

OPTIMIZATION MODEL FOR EVALUATING THE EFFECTIVENESS OF MARKETING CAMPAIGNS BASED ON A GENERALIZED FORMULATION OF THE TRANSPORTATION PROBLEM

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Abstract

In the modern marketing environment, the development of multi-channel communication systems, the deepening of consumer market segmentation, and the growth of data-driven management requirements determine the need for new methodological approaches to assessing the effectiveness of marketing campaigns. The limitation of marketing resources and the diversity of goals give rise to optimal allocation problems, the solution of which requires the use of mathematical modeling.

This article proposes a multidimensional mathematical model for planning and assessing the effectiveness of marketing campaigns, which is based on a generalized formulation of the transportation problem and is adapted to the specifics of marketing systems. The model allows for the optimal distribution of marketing resources between communication channels, target markets, strategic goals, and tools used, while ensuring minimal total costs and meeting the specified efficiency indicators.

The model structure includes the resource constraints of marketing channels, market demand, unit costs of channel-tool combinations, as well as efficiency ratios that reflect the level of marketing impact. The applicability of the proposed model is demonstrated through a numerical example and sensitivity analysis, which allow assessing the impact of changes in various factors on the optimal solution.

The results obtained show that the application of mathematical optimization approaches in the marketing management process provides a more efficient allocation of resources, contributes to the implementation of strategic goals, and can serve as a decision support tool for marketing managers and analysts.

Keywords: marketing campaign, effectiveness assessment, mathematical modeling, transportation problem, digital marketing mix, marketing management, optimization.

Introduction. The modern marketing environment is characterized by a variety of communication channels, deepening segmentation of consumer markets and the active use of data-driven management methods. The development of digital technologies has significantly changed the approaches to organizing and evaluating marketing activities, forming multi-channel communication systems, where each channel has its own cost structure, degree of influence and strategic significance [1, pp. 25–30; 2, pp. 41–45].

Marketing campaign planning and effectiveness assessment are currently considered not only as analytical functions, but as modern management technologies aimed at increasing the competitiveness of organizations [3, pp. 109–115; 4, pp. 98–102]. In conditions of limited resources, marketing managers are faced with problems of optimal resource allocation, the solution of which requires a systematic and quantitative approach.

In practice, most marketing decisions are based on experience, intuition, or simple analysis of historical data, which often does not ensure the maximum efficiency of resource use [5, pp. 175–178]. This circumstance determines the need to apply mathematical modeling and optimization methods in the marketing management process [6, pp. 12–18].

The transportation problem, as a classic linear programming problem, is widely used in various areas of resource allocation optimization: logistics, production, and supply chain [7, pp. 203–210]. However, in the marketing environment it requires adaptation, taking into account the multidimensional interdependence of channels, target markets, strategic goals, and tools used [8, pp. 55–61; 9, pp. 44–50].

The aim of this research is to develop a model for evaluating the effectiveness of marketing campaigns and optimizing their planning, based on a generalized formulation of the transportation problem and adapted to the specifics of marketing systems. The proposed model allows for quantitatively assessing the impact of different marketing channels and tools, ensuring optimal resource allocation, and justifying marketing decisions based on data-driven analysis [4, pp. 100–105].

The applicability of the model presented in the article is demonstrated through a numerical example and sensitivity analysis, which allow assessing the stability of the model and the effectiveness of its practical application under different scenarios.

Literature review. Modern marketing management systems are increasingly based on quantitative analysis and mathematical modeling [10, pp. 15–22]. The development of digital technologies has formed multi-channel communication systems (Omni-channel), where each channel has its own unique cost struc-

ture and strategic significance [11, pp. 88–95]. Marketing campaign planning is currently considered as a data-driven decision-making process aimed at increasing the competitiveness of the organization [12, pp. 210–215].

In the theoretical literature, the transportation problem is known as a classic tool for optimizing resource allocation [7, pp. 203–210]. However, as noted in research on the current state of marketing analytics, there is still a certain gap between theoretical models and practical application, which is due to the complexity and multidimensionality of marketing systems [13, pp. 114–120]. The use of quantitative modeling allows overcoming the shortcomings of intuitive management, which often lead to inefficient budget allocation [14, pp. 120–128].

The proposed model complements existing scientific approaches using the fundamental principles of Management Science [15, pp. 55–63]. By introducing an integrated system of efficiency ratios and time constraints, it becomes possible not only to minimize costs, but also to ensure the maximum level of marketing impact based on optimization algorithms.

Methodology. The methodological basis of this study is the approach of mathematical modeling and linear optimization, in particular, the generalized formulation of the transportation problem. The transportation problem is one of the classic problems of operations research and is widely used in various areas of resource allocation optimization [7, pp. 203–210]. Its adaptation to the marketing environment allows us to quantitatively describe the interrelationship of marketing channels, target markets, strategic goals and applied tools [8, pp. 55–61].

During the construction of the model, the methods of system analysis, quantitative modeling and simulation testing were used, which allow us to combine strategic and operational marketing goals within a single optimization framework [6, pp. 12–18].

The model includes the following indices:

i (i = 1, …, m) – marketing channels (social media, search advertising, television, etc.),

j (j = 1, …, n) – target markets or consumer segments,

k (k = 1, …, K) – marketing objectives (brand awareness, lead generation, sales),

r (r = 1, …, R) – marketing tools or communication formats (video, banners, email).

Parameters:

a_i^k – the total resource allocated to the i-th marketing channel for the k-th goal (budget, number of impressions, working time),

b_j^k - the demand of the jth target market from the perspective of the kth marketing objective (number of targeted contacts, leads or sales),

C_{ij}^{kr} - the unit cost of achieving the kth goal from the ith channel to the jth market through the rth marketing tool (CPA, CPM, CPC, etc.),

M_{ij}^{kr} - the available resource capacity (maximum allowable budget or number of actions) of a given channel-tool combination,

γ_{ij}^{kr} - the efficiency coefficient of a given channel-tool combination, which reflects the level of marketing impact (conversion rate, CTR, ROI),

t_{ij}^{kr} - the time spent on implementing one unit of marketing activity,

T_{ij}^{kr} - the total time limit set by the rth tool for the implementation of the k[th] goal.

Variable:

x_{ij}^{kr} - shows the intensity of achieving the kth goal from the i-th marketing channel to the j-th target market through the r-th marketing tool.

Objective function

The goal of the model is to minimize the total cost of the marketing campaign:

$$minF = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{K}\sum_{r=1}^{R} C_{ij}^{kr} X_{ij}^{kr}$$

Where C_{ij}^{kr} is the unit cost of a given channel-segment-goal-tool combination.

Constraints:

Full utilization of resources.

$$\sum_{j=1}^{n} X_{ij}^{kr} = a_i^k \qquad \begin{pmatrix} k = \overline{1,K} \\ r = \overline{1,R} \\ i = \overline{1,m} \end{pmatrix}$$

The marketing resources allocated from each channel must be fully utilized. In marketing, an unspent budget is considered a lost opportunity.

Meeting target requirements:

$$\sum_{i=1}^{m} X_{ij}^{kr} = b_j^k \qquad \begin{pmatrix} k = \overline{1,K} \\ r = \overline{1,R} \\ j = \overline{1,n} \end{pmatrix}$$

The marketing objectives set for each market must be achieved.

Equilibrium condition:

$$\sum_{i=1}^{m} a_i^k = \sum_{j=1}^{n} b_j^k \qquad \left(k = \overline{1,K}\right)$$

Total marketing supply = market demand. This is the basis of strategic planning.

Condition for variables to be non-negative.

$$X_{ij}^{kr} \geq 0, \qquad \begin{pmatrix} k = \overline{1,K} \\ r = \overline{1,R} \\ j = \overline{1,n} \\ i = \overline{1,m} \end{pmatrix}$$

There can be no negative advertising or negative influence.

Limitation of channel effectiveness:

$$\sum_{j=1}^{n} X_{ij}^{kr} = \gamma_{ij}^{kr} M_{ij}^{kr}$$

In marketing

γ- channel efficiency (ROI, CTR, CR),

M - budget, team strength, content productivity.

Time limit:

$$\sum_{j=1}^{n} t_{ij}^{kr} X_{ij}^{kr} = T_{ij}^{kr}$$

The campaign must be time-bound.

The proposed model is a multivariate linear optimization problem and can be solved by classical linear programming methods using the Simplex algorithm or appropriate numerical packages (e.g. LINGO, GAMS, Python PuLP, MATLAB Optimization Toolbox) [7, pp. 245–252].

The applicability of the model was assessed by numerical simulation, which allows analyzing different marketing resource allocation scenarios and their impact on overall efficiency [4, pp. 100–105].

Numerical example and analysis of results. To demonstrate the practical applicability of the model, let us consider an example of optimizing a marketing campaign, which includes 3 marketing channels (i=3), 3 target markets (j=3), 2 main goals (k=2) and 2 types of tools (r=2).

1. Description of input data. The available resources (budget) and market demand for each channel have been previously defined (Tables 1 and 2).

Table 1

Resource parameters of marketing channels

Marketing Channel (i)	Strategic Orientation / Focus	Total Budget (aik)
Social Media Ads	Brand + Engagement	1200
Search Ads	Sales + Leads	900
Display & Video Ads	Brand Awareness	1050

Table 2

Marketing Demand by Target Segments

Target Segment (j)	Brand Awareness	Lead Generation	Sales
Youth (18–25)	37	22	15
SMEs (Small & Medium Enterprises)	6	5	8
Corporate	14	3	6
Niche Market	17	2	4

2. Cost and efficiency parameters

The unit costs and efficiency ratios of each channel-tool combination are crucial for the optimization model.

Table 3

Cost Matrix for Digital Mix *(C_{ij}^{kr})*

Channel \ Segment	Youth	SME	Corporate	Niche
Social Media	20	2	1	5
Search Ads	15	4	4	3
Display/Video	13	2	2	3

Table 4

Effectiveness Coefficients for Digital Tools

Advertising Tool (r)	Strategic Role	Effectiveness Coefficient (γ)
Video Ads	Awareness	0.36
Search Ads	Conversion	0.72
Display Ads	Reach	0.25

3. Analysis and interpretation of numerical results

The numerical simulation results show that the proposed Marketing Analytics optimization framework provides an optimal allocation of marketing resources, combining strategic objectives and operational constraints of the digital mix.

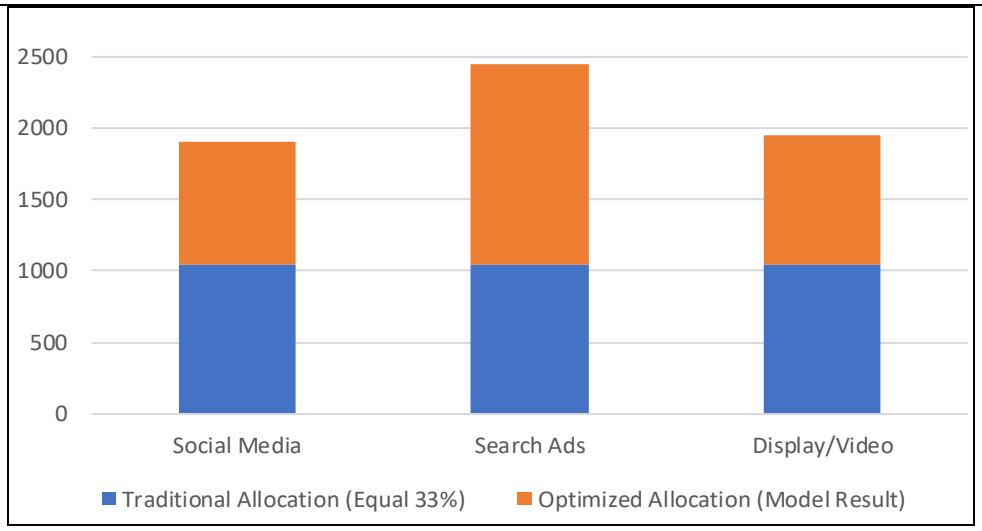

Figure 1.Comparative Analysis of Budget Allocation: Traditional Approach vs. Optimized Model

Figure 1 shows the budget redistribution after applying the model. As can be seen, as a result of optimization, a significant part of the resources was transferred to the Search Ads channel, which has the highest efficiency coefficient (γ =0.72), which allows to meet the demand of target segments with minimal costs.

The result of the model solution shows that tools with a high efficiency coefficient (γ = 0.72) are appropriate for performance-oriented goals, while tools with low efficiency, but providing a volumetric effect ((γ = 0.36) are more appropriate for ensuring brand recognition and accessibility.

Resource allocation by market.

In the first target market, the main part of the demand for brand communication is met through social media and video tools, while sales and conversion goals are achieved through search advertising.

For the second market, the optimal solution involves the combined use of digital tools, which allows to fulfill the demand with minimal additional resources.

In the case of the third market, the model suggests the predominant use of performance-oriented tools due to the limited availability of channels.

4. Sensitivity Analysis

In order to assess the stability of the model, a sensitivity analysis was conducted under the conditions of changing efficiency coefficients (γ).

The effect of increasing the value of γ = 0.36 to 0.45 was studied, which may be due to improving the quality of the content or adjusting the targeting. The results show that an increase in the efficiency coefficient leads to a greater marketing impact with the same budget and reduces the need for additional digital placements.

At the same time, the scenario of a decrease in the coefficient γ = 0.72 (for example, due to increased competition or increased CPC) indicates that the implementation of performance-oriented goals requires greater resource involvement, which may affect the effectiveness of the overall marketing strategy.

5. Managerial Implications

The results obtained enable marketing managers to use the proposed model as a decision support tool in the process of marketing strategy and digital mix formation. The model allows for a preliminary assessment of the effectiveness of various channels and tools, optimize budget allocation, and reduce marketing risks based on data-driven analysis.

Conclusion. Within the framework of this research, a model for assessing the effectiveness of marketing campaigns and optimizing resource allocation, which is a modern Marketing Analytics technology, was developed and experimentally substantiated. The proposed mathematical framework allows integrating strategic goals and operational constraints of the digital mix into a single system.

The main results of the research are summarized in the following points:

Methodological novelty. It was shown that approaches to the optimization of classical transportation problems can be successfully adapted to the marketing environment by introducing the concept of efficiency coefficients (γ). This allows us to quantitatively assess the impact of different channels and tools.

Practical applicability: Numerical simulation and sensitivity analysis confirmed that the model provides optimal resource allocation and demonstrates sufficient flexibility in conditions of dynamic changes in the external environment (for example, an increase in advertising costs).

Managerial value: The results obtained can serve as a decision support tool for marketing managers, reducing the risks of intuitive decisions and justifying budget allocations with data-driven analysis.

For further research, it is promising to expand the model to include dynamic time horizons and competitive environment variables. Accounting for the interaction of multi-stage marketing campaigns will allow us to further increase the accuracy of the model in complex and multi-layered market conditions.

References:

1. Kotler, P., & Keller, K. L. (2016). *Marketing management* (15th ed.). Pearson Education.

2. Chaffey, D., & Ellis-Chadwick, F. (2019). *Digital marketing: Strategy, implementation and practice* (7th ed.). Pearson Education.

3. Rust, R. T., Lemon, K. N., & Zeithaml, V. A. (2004). Return on marketing: Using customer equity to focus marketing strategy. *Journal of Marketing*, 68(1), 109–127. https://doi.org/10.1509/jmkg.68.1.109.24030

4. Wedel, M., & Kannan, P. K. (2016). Marketing analytics for data-rich environments. *Journal of Marketing*, 80(6), 97–121. https://doi.org/10.1509/jm.15.0413

5. Hanssens, D. M., & Pauwels, K. (2016). Demonstrating the value of marketing. *Journal of Marketing*, 80(6), 173–190. https://doi.org/10.1509/jm.15.0417

6. Winston, W. L., & Goldberg, J. B. (2004). *Operations research: Applications and algorithms*. Duxbury Press.

7. Taha, H. A. (2017). *Operations research: An introduction* (10th ed.). Pearson Education.

8. Lilien, G. L., Rangaswamy, A., & De Bruyn, A. (2019). *Principles of marketing engineering*. DecisionPro.

9. Bertsimas, D., & Tsitsiklis, J. N. (1997). *Introduction to linear optimization*. Athena Scientific.

10. Wedel, M., & Kannan, P. K. (2016). *Marketing Analytics for Data-Rich Environments*. Journal of Marketing, 80(6), pp. 15–22.

11. Verhoef, P. C., et al. (2015). *From Multi-Channel Retailing to Omni-Channel Retailing*. Journal of Retailing, 91(2), pp. 88–95.

12. Farris, P. W., et al. (2021). *Marketing Metrics: The Manager's Guide to Measuring Marketing Performance*. Pearson Education, pp. 210–215.

13. Germann, F., Lilien, G. L., & Rangaswamy, A. (2013). *The State of Marketing Analytics in Research and Practice*. Journal of Marketing Theory and Practice, 21(3), pp. 114–120.

14. Hanssens, D. M., & Pauwels, K. H. (2016). *Demonstrating the Value of Marketing*. Journal of Marketing, 80(6), pp. 120–128.

15. Bertsimas, D., & Freund, R. M. (2004). *Data, Models, and Decisions: The Fundamentals of Management Science*. Dynamic Ideas LLC, pp. 55–63.

INTEGRATING THE SUSTAINABLE DEVELOPMENT GOALS INTO GLOBAL SUPPLY CHAIN PERFORMANCE METRICS: AN INTERNATIONAL FRAMEWORK

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Abstract

The integration of the Sustainable Development Goals (SDGs) into global supply chain performance measurement has become a strategic priority for firms seeking long-term resilience and legitimacy. While existing sustainability metrics address environmental and social dimensions, they often lack alignment with internationally recognized SDG indicators. This study develops an internationally compatible framework for embedding SDGs into global supply chain performance metrics. Building on recent empirical and conceptual studies, particularly Alizada and Ibrahimov (2026), the paper synthesizes sustainability, operations, and governance perspectives. The findings indicate that SDG-integrated metrics enhance transparency, comparability, and strategic decision-making across global value chains, while also supporting regulatory and stakeholder alignment.

Keywords: Sustainable Development Goals, Global supply chains, Performance metrics, Transparency, International standards, Governance

Introduction

Global supply chains play a pivotal role in achieving sustainable development outcomes, as they significantly influence patterns of resource utilization, labor standards, environmental impacts, and economic value creation across national and regional boundaries (United Nations, 2015). In an increasingly interconnected global economy, supply chains determine not only how goods and services are produced and distributed, but also how social and environmental responsibilities are shared among countries, firms, and stakeholders. Consequently, the performance of global supply chains has become a critical determinant of progress toward the Sustainable Development Goals (SDGs), particularly in areas such as decent work, responsible consumption and production, and climate action.Despite this growing importance, traditional supply chain performance measurement systems have largely prioritized operational and financial indicators, including cost minimization, quality assurance, delivery speed, and flexibility. While these metrics remain essential for competitiveness, they often fail to capture the broader environmental and social externalities generated along global value chains (Carter & Rogers, 2008). As a result, many organizations lack a comprehensive understanding of how their supply chain activities contribute to—or undermine—long-term sustainability objectives. This limitation has led to fragmented sustainability initiatives that are weakly integrated into core operational decision-making processes.The adoption of the 2030 Agenda for Sustainable Development has fundamentally reshaped expectations regarding corporate responsibility and supply chain governance. Organizations are now under increasing pressure from governments, international institutions, investors, and civil society to align their operational performance with the SDGs and to demonstrate measurable contributions to global sustainability targets (UN SDGs, n.d.). This shift has intensified the demand for performance measurement frameworks that go beyond voluntary reporting and enable systematic, transparent, and comparable assessment of sustainability outcomes within global supply chains.Recent academic and policy-oriented research highlights the urgent need for standardized and internationally comparable metrics that can effectively translate the SDGs into operational indicators applicable across diverse supply chain contexts (Seuring & Müller, 2008; Alizada & Ibrahimov, 2026). Such metrics are essential for reducing ambiguity in sustainability reporting, enhancing cross-border comparability, and supporting evidence-based decision-making at both firm and policy levels. In particular, aligning supply chain performance indicators with globally recognized SDG targets can strengthen coherence between corporate strategies and international sustainability governance frameworks.Addressing this gap, the present study proposes an SDG-integrated supply chain performance framework that is consistent with international guidelines and sustainability governance structures. By embedding SDG targets into core performance dimensions, the framework aims to enhance transparency, improve accountability, and facilitate strategic alignment between global supply chain operations and sustainable development objectives. In doing so, the study contributes to the evolving literature on sustainable supply chain management by offering a structured and internationally relevant approach to performance measurement in the context of the 2030 Agenda.

Literature Review

The literature on sustainable supply chain management (SSCM) reflects a clear evolution from a narrow focus on environmental compliance toward a more comprehensive and integrated approach encompassing economic, environmental, and social performance dimensions. Early contributions to the field were largely

concerned with reducing negative environmental impacts and ensuring regulatory compliance. However, the introduction of the triple bottom line framework by Elkington (1997) marked a critical turning point by emphasizing the need to balance economic viability with environmental stewardship and social responsibility. Building on this foundation, Ahi and Searcy (2013) demonstrate that contemporary definitions of SSCM increasingly recognize sustainability as a multidimensional and strategic concept rather than a purely operational or compliance-driven concern.Carter and Rogers (2008) provide one of the most influential conceptualizations of SSCM by defining it as the strategic integration of sustainability objectives into key supply chain processes, including sourcing, production, logistics, and distribution. Their framework highlights the interdependence between sustainability initiatives and traditional supply chain goals such as efficiency, risk reduction, and competitive advantage. Complementing this perspective, Pagell and Wu (2009) focus on the inherent trade-offs and managerial decision-making challenges associated with implementing sustainable supply chain practices. They argue that achieving sustainability often requires organizations to rethink established performance priorities and accept short-term costs in exchange for long-term resilience and value creation.More recent strands of the literature extend the SSCM discourse by explicitly linking supply chain sustainability to global policy and governance frameworks, most notably the Sustainable Development Goals (SDGs). International organizations such as the OECD (2021) and the World Economic Forum (2022) emphasize the role of global supply chains as critical transmission mechanisms through which international sustainability objectives can be operationalized. These studies highlight the growing expectation that firms align their supply chain strategies and performance measurement systems with internationally recognized sustainability targets, thereby strengthening accountability and policy coherence across borders.Within this emerging research stream, Alizada and Ibrahimov (2026) make a significant contribution by empirically mapping SDG targets to specific supply chain performance dimensions. Their framework demonstrates that SDG-aligned metrics can enhance strategic coherence, improve measurability, and facilitate clearer communication between firms and external stakeholders. By translating abstract global goals into operationally relevant indicators, their study addresses one of the key limitations identified in earlier SSCM research.Despite these advances, the literature consistently points to several unresolved challenges in integrating SDGs into supply chain performance measurement. Scholars note persistent difficulties related to data availability, particularly in multi-tier and geographically dispersed supply chains, as well as problems of indicator harmonization across different regulatory and institutional contexts (Brandenburg et al., 2014). Furthermore, cross-country comparability remains a major concern, as variations in reporting standards, technological capacity, and institutional quality can undermine the consistency and reliability of sustainability metrics (Dubey et al., 2017). These challenges underscore the need for internationally compatible and governance-aligned frameworks capable of supporting robust and comparable sustainability performance assessment in global supply chains.

Research Questions and Hypotheses

RQ1: How can SDGs be systematically integrated into global supply chain performance metrics?

RQ2: Does SDG-aligned measurement improve transparency and comparability across global value chains?

RQ3: What institutional factors support effective SDG integration?

H1: SDG-integrated performance metrics positively influence supply chain transparency.

H2: Alignment with international sustainability standards enhances cross-border comparability.

H3: Firms adopting SDG-based metrics demonstrate stronger long-term supply chain resilience.

Methodology

This study employs a qualitative integrative research design based on systematic literature review and framework synthesis. Peer-reviewed journal articles, international organization reports, and sustainability standards were analyzed (Seuring & Müller, 2008; ISO, 2017). Particular emphasis was placed on the empirical framework proposed by Alizada and Ibrahimov (2026), which was evaluated against international sustainability guidelines (UN, OECD, ISO). The analysis focused on identifying convergent indicators and governance-compatible performance dimensions.

Results and Discussion

The analysis reveals that SDG-integrated supply chain metrics improve strategic alignment between corporate operations and global sustainability agendas. Metrics linked to SDGs 8, 12, and 13 are most frequently operationalized through procurement, logistics efficiency, and emissions management indicators (Genovese et al., 2017; Fahimnia et al., 2015). The framework adapted from Alizada and Ibrahimov (2026) demonstrates strong compatibility with international standards when contextualized within ISO 20400 and UN Global Compact principles.Nevertheless, challenges remain, including data standardization across regions and the cost of monitoring complex global value chains (Sarkis et al., 2011; OECD, 2021). Addressing these issues requires stronger institutional coordination and digital reporting infrastructures.

Conclusion

Integrating SDGs into global supply chain performance metrics represents a critical step toward sustainable and resilient global value chains. This study shows that internationally aligned SDG-based frameworks enhance transparency, comparability, and strategic coherence. Building on Alizada and Ibrahimov (2026), the paper contributes to SSCM literature by offering a governance-compatible measurement perspective. Future research should focus on quantitative validation and sector-specific indicator development.

Materials

Policy documents, sustainability standards, and secondary datasets from international organizations were used in this study.

References:

1. Alizada, T., & Ibrahimov, Ə. (2026). Integrating SDGs into global supply chain performance metrics: A new empirical framework. Zenodo. https://doi.org/10.5281/zenodo.18386299
2. Ahi, P., & Searcy, C. (2013). A comparative literature analysis of definitions for green and sustainable supply chain management. Journal of Cleaner Production, 52, 329–341. https://doi.org/10.1016/j.jclepro.2012.12.008
3. Brandenburg, M., Govindan, K., Sarkis, J., & Seuring, S. (2014). Quantitative models for sustainable supply chain management. European Journal of Operational Research, 233(2), 299–312. https://doi.org/10.1016/j.ejor.2013.08.031
4. Carter, C. R., & Rogers, D. S. (2008). A framework of sustainable supply chain management. International Journal of Physical Distribution & Logistics Management, 38(5), 360–387. https://doi.org/10.1108/09600030810882816
5. Dubey, R., Gunasekaran, A., Childe, S. J., et al. (2017). Big data analytics and sustainable supply chain performance. International Journal of Production Economics, 185, 90–105. https://doi.org/10.1016/j.ijpe.2017.03.008
6. Elkington, J. (1997). Cannibals with forks: The triple bottom line of 21st century business. Capstone.
7. Fahimnia, B., Sarkis, J., & Davarzani, H. (2015). Green supply chain management. European Journal of Operational Research, 242(3), 845–856. https://doi.org/10.1016/j.ejor.2014.01.022
8. Genovese, A., Acquaye, A. A., Figueroa, A., & Koh, S. C. L. (2017). Sustainable supply chain management and the transition towards a circular economy. International Journal of Production Research, 55(23), 6932–6948. https://doi.org/10.1080/00207543.2017.1370159
9. ISO. (2017). ISO 20400: Sustainable procurement — Guidance. https://www.iso.org/standard/63026.html
10. OECD. (2021). Global value chains and sustainability. https://www.oecd.org/trade/global-value-chains/
11. Pagell, M., & Wu, Z. (2009). Building a more complete theory of sustainable supply chain management. Journal of Supply Chain Management, 45(2), 37–56. https://doi.org/10.1111/j.1745-493X.2009.03162.x
12. Sarkis, J., Zhu, Q., & Lai, K. H. (2011). An organizational theoretic review of green supply chain management literature. International Journal of Production Economics, 130(1), 1–15. https://doi.org/10.1016/j.ijpe.2010.11.010
13. Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. Journal of Cleaner Production, 16(15), 1699–1710. https://doi.org/10.1016/j.jclepro.2008.04.020
14. United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. https://sdgs.un.org/2030agenda
15. United Nations Sustainable Development Goals. (n.d.).https://sdgs.un.org/goals
16. World Economic Forum. (2022). Global supply chain resilience report. https://www.weforum.org

HISTORICAL SCIENCES

THE ROLE OF CREATIVE INTELLECTUALS IN THE DEVELOPMENT OF AZERBAIJAN CULTURE (1960 – 1980s)

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Abstract

The important factors that play the decisive role in the formation and evolution of every nation are among the important and extremely significant processes that emerge in the course of historical events that humanity has always faced and thought about, on the scene of difficult and intense struggles and thanks to them. Thus, the process of formation, growth, purification and development of the nation is directly connected in the formation, emergence, evolution process of its intellectuals and other actual issues. When the society develops its intellectuals, it develops itself, constantly gaining the incomparable achiements in the various fields of education and science, strengthening its scientific potential and striving for innovations, development, progressive methods, realism and modern scientific achievements based on accurate facts. Every intellectual is the bright child of his nation, its healthy and progressive thinking, scientific potential, creative person and the very valuable treasure of science. The creativity of each intellectual means his main field of activity, the extremely valuable scientific achievements he has gained as a result of his hard work, effort and many years of intense struggle, the urgent problems he has raised, the works he has found solutions to and investigated, the new paths he has opened, the new areas of scientific research he has identified, the intense researches and searches he has conducted, the scientific results he has reached, the important scientific issues he has raised, etc. The intellectuals, working in these fields, constantly develop, improve, modernize, enrich them with the progressive ideas, and seek and find the solutions to problems that meet the requirements of modern science, thereby forming themselves as true scientists and intellectuals in this way. In this regard, the activity of creative intellectuals is the shining example of their talent and ability, skills and smartness. The scope of activity of the creative intellectuals is quite wide and covers all spheres of culture. The cultural problems are always very actual and distinguished by their diversity, uniqueness, characteristic features, reference to real facts, and at the same time, being the product of the artist`s artistic imagination. The creative intellectual, as an artist, enriches the field he works in by working on it and makes it colorful with his creativity, as well as with his beautiful works, heroes, plots, talent, skills and abilities, as a result, the culture is enriched, with the different and unique creative colors it becomes interesting, attractive, thought provoking, perfect in terms of ideas, fluent, national in form, and realistic in content. İn this regard, the role played by the creative intellectuals in the development of Azerbaijan culture is particularly noteworthy.

Keywords: creative intellectuals, creativity, Azerbaijan, culture, development, problems, activity, researches

İntroduction

The development of culture is one of the main issues facing every society. The culture can be considered as one of the areas that plays the important role in the formation, improvement, progressive development and functioning of society in civil and legal aspects. As the culture develops, so does society, the education and science take on their true and colorful hues, ensuring that people walk on the right way, in the direction of progressive and conscious formation. From this point of view, the culture should be studied, propagated, disseminated, researched, investigated, and should be one of the decisive directions of relations. The study of culture is the multifaceted process and involves all its areas in the scientific research in the equally effective and fair manner. The scientific study, analysis, investigation of culture means ensuring its development away from its artistic and entertainment character and towards more realism, the logical explanation, interpretation, study and successful resolution of events. The culture is such field that should enligthen, teach, educate, guide and form not only the scientists and intellectuals, but also other segments of society. All areas of culture are of exceptional importance in the formation of a person as a personality. The person who is familiar with the various areas of culture gradually forms these positive and realistic qualities in himself and begins to function in the society as the perfect and mature personality. Such people bravely face all the difficulties, tortures and injustices of the modern world and always win, becoming the real and vivid example of the image of the cultured, mature, educated, conscious and progressive person in life. The propaganda of culture is one of the most important issues. The propaganda is the most powerful and effective way of the modern world and plays the decisive role in the process of education and proper formation of people. Thus, the person who is familiar with the latest achievements of science and technology tries to bring these innovations into his real life, beauty, creativity, experience and daily activity. These efforts ultimately lead to the diverse development and renewal of the various spheres of culture, the spread of progressive ideas and trends to culture, and the progress of education and science. That is why the propaganda

of culture is of great importance and it should make the positive contribution to the upbringing, life, worldview and formation of people, not on the wrong path, but on the right path. In this regard, the study of culture can help to make the propaganda more efficient and effective, enriching it with the scientific facts, correct analyses and works. The process of studying culture requires the scientists to develop positive qualities such as great responsibility, intellectual conscience, endless hard work, broad outlook, etc., and only then can the problems facing the culture be properly studied. The culture is also one of the decisive directions of relations. Thus, people express their identity as the representatives of different nations in their works, handicrafts, creative examples, etc. in diverse forms, and enrich them with their workdviews, talents and skills, progressive ideas, innovations and individual characteristic features. The role and activity of the creative intellectuals are of exceptional importance in this work.

1.The formation of creative intellectuals

Each era has its own requirements, criteria, development directions and trends. It is extremely important to keep up with the current socio – political environment and situation of the era, to have the deep understanding of it, to have the ability to analyze it, to solve it correctly, to always fight against difficulties, not to submit to injustice, not to remain silent in the face of injustice, to always listen to the voice of conscience and to form another superior and positive qualities in oneself and bring them to the creativity in completely different aspects. Thus it is important and purposeful for the ideologically mature person to take an active position in society [21, p.3]. A person is formed, developed, educated and become a personality in society. An artist, working conscientiously and responsibly in the various fields of culture, overcomes all the difficulties and obstacles on the way to professional craftsmanship, matures, specializes and gradually becomes the professional specialist, entering the honorable stage as the skilled connoisseur of his art. The culture, in all its spheres and directions, refers entirely to the creative process. The creativity is the direct field of the activity of creative intellectuals and is based on the development strategy such as gradual learning, preparation, specialization, gaining experience, working, putting theoretical knowledge into the practical work, growth, maturity and comprehensive formation. An artist must always improve and develop his art, regardless of the society in which he lives. The creative intellectuals can be considered the creators, carriers, developers, disseminators of culture and the main means of expanding relations [21, p.8].

Finding the creative individuals in society, revealing their skills and abilities, not destroying talented and special – talented individuals, but rather preserving them, further developing this talent and preparing them as artists with a broad worldview, excellent education, deep knowledge of rare examples of art of world culture, comprehensive preparation and with exquisite taste can be considered one of the most important problems facing society and the period. The culture requires creativity. The creativity requires art and craftsmanship. The art must be created and developed by an artist. It is essential to reveal an artist as a rare talent, educate, teach, train, develop, mature and shape. The appropriate conditions should be created for the training of creative individuals, and the state`s policy and strategy should not be based on the destruction of such talented children of the people, but on their preservation, protection, development and assistance in taking their worthy place in the modern complex world. The intellectuals engaged in the artistic creativity should strive to fulfill these tasks. The research scientist, Doctor of Historical Sciences, Professor Nisbet Mehdiyeva, who has studied the formation, activity and role of creative intellectuals very well, shows that the historical process combines the wide range of cultural events, and the artistic creativity occupies the important place in it. The artistic creativity is a cultural phenomenon. The development of culture is the integral part of the general historical process [21, p.10] (İmage 1).

Image 1. The research scientist, Doctor of Historical Sciences, Professor Nisbet Mehdiyeva

Everyone has the right to participate in cultural life, to use the cultural institutions and cultural resources. However, the creative intellectuals participate in this cultural process not as the spectators or listeners, but as the creative one. The creative intellectuals write beautiful works, compose playful, cheerful and rich music, create unique paintings, erect charming statues, prepare the projects for beautiful architectural monuments, play interesting roles and stage beautiful performances, screen deep and thought provoking documentaries and feature films, write librettos and scripts for them, compose various colorful and solemn music for performances, animation and movies. The training and formation of professional creative personnel – creative intellectuals who skillfully operate in such a wide range of fields require the special care, attention, assistance from the state, and the special state policy for the protection and preservation of creative individuals. From this point of view, the training of creative intellectuals in the republic in the 60 – 80s of the XXth century, the finding of talented individuals, the granting of freedom of creativity and activity to them, the improvement of their qualifications from time to time, the emergence of the concept of professional intellectuals – creators, the provision of state care for them, and the protection of creative individuals with refined taste from unpleasant situations and cruelty encountered in the society should be considered among the most important and actual issues facing the state, the people, and society.

During this period, the great importance was attached to aesthetic education in our country. In this regard, the promotion of self – activity and professional creativity by all means, the identification of only talented individuals completely gratuitously, their involvement in the cultural life of the country, their education in the relevant arts in order to engage in professional creativity, their study, internship, preparation, specialization and the solution of such issues were of great importance [22, p.3].

The various competitions, meetings, discussions, disputes, reports read by the professional artists in the various creative fields to young and talented creative individuals, creative reports, audience conferences, organization of performances by amateur and artistic amateur associations, activity of their leaders and employees, meetings with the members of drama associations and amateur collectives operating under the various military units and organizations and other such actual events play an exceptional role in the discovery and development of creative individuals. The scope of influence of the audience conferences held by the Azerbaijan Theater Society is very wide. Such conferences were attended by heads of organizations, heads and employees of drama clubs, representatives of the Baku City Public Education Department and members of other organizations. Thus, in 1971 – 1972, the Young Spectator Theater held more than 50 large – scale events on a city and regional scale. Among them theoretical conferences, organization of exhibitions of children`s drawings, creative meetings of young poets and playwrights, etc. were of great importance. The young activists of the theater, united in the art club, created the sections for actors, theater critics, naturalistic design, etc. The main task of these associations and sections was to identify, educate, prepare and shape talented individuals in the existing environment [17]. Thus, more than 15 thousand people participated in more than 20 audience conferences held in Baku in 1962 alone. The discussions of various films were held here, and important aspects such as the creation of films, the preparation of films, the writing, discussion, and filming of scripts, the organization of the work of actors and directors, the formation of actor – audience relations, the selection of a professional acting team, ensuring that the director`s imagination does not harm the main idea of the work, artistic and design issues, etc. were in the spotlight. During this period, the newspaper "Movie updates", which began to be published in the republic in the 60s of the XXth century, covered in detail the advertising of motion pictures, the filming, preparation and distribution of cinematographic works, the activity of the creative team, the working principles and other creative issues [22, p.22].

The activity of the Union of Artists aimed at the development of fine arts and aesthetic education in secondary schools played the decisive role in the education of children and youth, their formation and activity as future creative individuals. Thus, the demand for works of fine arts in libraries increased, art exhibitions and writing of essays of the various contents related to individual works of art took on intensive character, exhibitions organized from children`s handicrafts, decorating the class-rooms and corridors of schools with the best art and painting samples selected from handicrafts of talented children and youth, etc., encouraging and creative methods began to gain wide popularity. The members of the Union of Artists of the Republic gave 85 lectures in 1960 and 102 reports in 1962 [7; 9].

The role of folk universities in the process of emergence and formation of the creative intellectuals was of particular importance. Since 1959, the folk universities have begun to be established in Azerbaijan. The new branches of folk culture universities, which play an important role in the moral education of people, began to emerge and spread. Among them the university of music, the university of cinema, the university of social sciences, the film university of parents, the university of health, etc. were especially distinguished. The special attention was paid to the work and development of cultural universities. Thus, in order to properly direct the activity of folk cultural universities, the Republican Public Council was created, as well as another public council consisting of the representatives of cultural organizations, societies that disseminate the political and scientific knowledge – trade unions and creative unions [22, p.26 – 27]. In 1959, the University of Culture was organized within the Azerbaijan Composers` Union [1]. In 1961 alone, 84 lectures were delivered and creative meetings were held through the cultural universities [2].

İn 1960, it was decided to create a special group of lecturers to strengthen the activity of cultural universities on the union and republican scale [5]. Thus, the Republican Union of Artists has begun the practical activity to assist the work of cultural universities organized in cultural palaces and various institutions [22, p.28]. The Union of Artists organized 67 lectures on the wide popularization of art and various issues of fine arts. The

artists and art critics delivered the speeches on the various topics “Azerbaijan applied art in 40 years”, “Types and genres of applied art”, etc. at folk universities established in the various institutions and organizations operating in Baku and the regions of the republic [6].

The Union of Cinematographers organized the group of 15 lecturers in 1960 – 1961 to assist the cultural universities. They delivered the lectures on various topics reflecting important issues facing the art of cinema, such as “How to Create a Motion Picture”, “How to Shoot a Motion Picture”, “On the History of Azerbaijan Cinema”, etc. The members of the Union of Cinematographers delivered more than 400 lectures at cultural universities during this period [22, p.28]. The Union of Cinematographers organized the folk faculty, folk university of cinema art at the “Vatan” cinema, film club, etc. In 1976 – 1980, the film scholars, critics, directors and actors held 165 workshops across the republic [25, p.9]. The folk film university was established at the “Azerbaijanfilm” studio. The talented and skilled young people were attracted to this university, who were trained to enter relevant institutes and make amateur films [22, p.29]. As can be seen, the cultural universities played the exceptional role in the sphere of identifying talented and specially gifted individuals, preparing them for future professional education, and forming them as prepared creative individuals in various fields.

In 1959, the directors and soloists of the Azerbaijan State Academic Opera and Ballet Theater gave the various lectures at cultural universities on topics such as “How to listen and understand music”, “Opera Art”, etc. [11].

By presenting topics of various natures, the audience of listeners and spectators had the opportunity to learn the intricacies of professional art, to deeply understand it, and to get favourable conditions for the emergence of talented and capable individuals who wanted to work through art. At the same time, the creative intellectuals represented in various creative unions, working and engaged in professional art, were striving to raise the level of the lectures and reports they gave. Depending on the nature of each activity, the visual and colorful illustrative materials were enriched and were increasingly accompanied by the screening of documentary films with topical content, performances by artists of the Opera and Ballet Theater, exhibitions, stands, the compilation of photo albums, the organization of photo galleries, the presentation of photo stands and videos collecting handicrafts and art samples of amateur and young creative individuals, etc. İn addition, the various excursions of educational and moral significance organized to the historical and architectural monuments of Baku could also be considered one of the important elements in this regard. Such cultural universities, which combine several fields of art, played the very important role in finding, revealing, training, preparing creative individuals, enriching their worldview, acquiring creative knowledge, skills and gradually forming [22, p.29].

İn the 60s and 70s of the XXth century, the number of folk universities operating in the republic increased. İn 1968 – 1969, there were 237 folk universities with 26.900 listeners, in 1971 – 1972, there were 273 folk universities with 36.198 listeners, and in 1979 – 1980, there were 671 folk universities with 123.700 listeners [22, p.29 – 30].

It should be noted that the activity of each folk university were evaluated not only by the number of listeners and lectures given there, but also by the quality of the classes, the impact of the lectures and classes on the licteners, and the diversity of effective creative forms, methods and techniques used by the artists working there in their search for talent. In folk universities, the diverse creative forms and methods such as seminars, debates, questions and answers, discussions, film screenings and audience discussions, etc., were sometimes used rather poorly. The theaters, concert organizations, film studios and other organizations also provided some assistance for the normal functioning of folk universities. However, it should also be noted that the level of regular practical activity and assistance provided by certain organizations to the folk universities in terms of assigning lecturers and providing them with relevant textbooks, teaching aids, etc. was somewhat low [22, p.30].

The Azerbaijan Creative Unions have constantly fought for the formation of the people in the ideological and educational environment in the country, purely creative atmosphere of talented individuals, and in general, people`s refined aesthetic taste and the professional art of creative intellectuals [22, p.35].

The self – activity creativity operating in the republic also played the unique role in the formation of creative intellectuals. In 1975, the cultural and artistic figures took care of some self – activity collectives in connection with the holding of the First Republican Festival of Artistic Self – Activity Creativity [22, p.39]. In this work, the Creative Unions also maintained the extensive contact with libraries, clubs and other cultural – educational institutions [22, p.46].

The “Creative Meetings Club”, established in the country in the 60s of the XXth century, included writers, composers, artists, architects, and other creative intellectuals. The purpose of organizing this club was to strengthen creative relations between the professional and young creative intellectuals working in various fields of literature and art in the country and to ensure the growth and formation of talented individuals in a purely creative environment [24].

The Republican Union of Composers actively participated in the creation of music clubs in the cities and regions of the country. The strengthening of the activity of music schools in the 70s of the XXth century allowed the creation of young musicians` club and folk orchestras` collectives [19].

The care for the development of artistic self – activity and supporting their activity were considered one of the main tasks of the creative unions. The folk theaters are the most widespread type of self – activity collectives. They are one of the active types of art that connect folk creativity with professional craftsmanship and play the important role in the formation of creative intelligentsia. As society developed, the process of mutual enrichment of artistic self – activity and professional art intensified. In the performances and speeches of folk creativity – artistic self – activity collectives, represented by various amateur associations and

groups, sometimes such elements, plots, structures and creative lines are found that are impossible to find in the performances included in the repertoire of professional theaters. The artistic self– activity develops its creativity in all types of art and thereby improves and forms. The development of artistic folk art was encouraged by various means. The folk theaters were established in our country in 1953. İn 1962, 17 such folk theaters were operating [8]. In 1963, the Azerbaijan Theater Society decided to regularly send directors, artists and actors to assist folk theaters, share creative advices and experience [15]. As a result of about 20 visits to folk theaters in 1963, it became clear that among the folk theaters there were the talented collectives, individual promising amateurs and talented persons. That is why the permanent commission was created in the Theater Society to assist the folk theaters [16]. Thus, in 1969, there were 1.427 artistic self – activity collectives in the country. Among them, 559 choirs, 928 drama groups, 290 choreographic groups, 277 folk instrumental orchestras, 148 instrumental ensembles, 345 artistic propaganda brigades, 425 children`s self – activity collectives, etc. can be mentioned [22, p.51]. Already in 1980, 12.549 artistic self – activity collectives with 214.746 participants were operating in the republic [22, p.52]. At the same time, the establishment of "Amateur associations", "Interest clubs", "Youth clubs", "Aesthetic education clubs", etc. clubs were also in the spotlight [22, p.53].

The activity of amateur film studios and film clubs was satisfactory. In 1960, the amateur films were discussed and advices were given at the meetings of the Organizing Bureau of the Union of Cinematographers of Azerbaijan and the section of the Cinema House for film enthusiasts [12]. Thus, the amateur film studios have been established in the various organizations and institutions [13].

The Azerbaijan Composers Union paid the special attention to the development of young musical collectives – song and dance ensembles. In order to raise their level of creativity, prominent composers, ballet masters and other professional creative intellectuals were assigned to these ensembles. The outstanding composer A.Malikov, while still a student of the Azerbaijan State Conservatory, took an active part in the public service assigned to the artistic self – activity collectives [3]. In 1961 – 1963, the various professional composers gave the creative advices and instructions to youth theaters, artistic self – activity associations, pop orchestras, and choral groups operating in the republic`s enterprises and organizations [4].

This creative assistance and cooperation led to the maturation, development, and experience of artistic self – activity collectives, and their formation as increasingly professional creative intellectuals in a purely creative environment.

The Azerbaijan artists used the various forms and methods to promote the development of artistic self – activity associations and collectives. In 1960 – 1961, 10 members of the Union of Artists led the self – activity associations and held advices hours for amateurs [10]. In 1960 – 1961, the republican exhibition of works by amateur artists was held. The target was to reveal young talents through the self– activity. For this purpose, the Union of Artists organized the seminars and advices hours for amateur artists, held discussions and reviews of their works, organized exhibitions, and took the various practical measures to direct their creative activity [22, p.55].

The Republican Creative Unions, taking the practical action to create a purely creative environment in the country, regularly worked to form the professional, highly intellectual creative persons from young and amateur talented individuals, and constantly fought in the creative and progressive way to achieve the level of professional intellectuals.

2. The role of creative intellectuals in the field of development of Azerbaijan culture

The creative intellectuals – writers, composers, directors, actors, film workers, etc., playing the important role in the development of culture in the country, have always been distinguished by their creative, progressive and positive approach to the various areas of culture, search for new creative ideas and innovations, discovery and professional development of innovation, non – destruction of previous elements and samples, but rather their preservation and development, preservation of the uniqueness of each nation and other characteristic features. From this point of view, the importance of artistic culture, its objective position in the correct formation and enrichment of the people`s moral worldview, close acquaintance with the most progressive and positive cultural examples of the world, correct and honest understanding and assimilation of them, right stance against the events, injustice and lawlessness encountered in life, etc. is extremely necessary in resolving issues.

The artistic culture makes the people think, explains, teaches, gives direction, shows what is right and what is wrong, reveals and exposes injustice, invites the people to refrain from bad deeds, educates them, and constantly fight conscientiously and responsibly to bring the most honest and humane features to real life by describing the image of the perfect person. The culture should be understood and understandable by the broad masses of the people and society, express the feelings and desires of the people, combine them in their creative works, write, draw, express, show and disseminate them. Such culture has a deep ideological content, mature artistic craftsmanship, and diverse form, genre and style. The artistic creativity is a complex and multifaceted process, but it is also characterized by its diversity. The artistic creativity is the artistic embodiment and collection of the artistic imagination, the style of ideas, the forms and methods, the various images, thoughts, and ideas created and used in the works by the creative intellectuals such as writers, poets, painters, sculptors, directors, actors, etc. It is extremely important to raise the ideological and political level and professional skills of the creative intellectuals who play the role in the development of culture. Such talented creative intellectuals, represented in the creative unions, fall into a purely creative environment and had the favorable conditions to improve their professional skills, become true professionals, and participate in the development of culture. However, the freedom, independence, and personal liberty given to each artist

in the creative unions to develop their individual characteristics has been the very progressive and positive development and has played the decisive role in the development of culture [21, p.31 – 32]. The Writers` Union (1934), Composers` Union (1934), Artists` Union (1940), and Cinematography Workers Union (1958) were established in Azerbaijan. The Theater Society (1948), the public creative organization of theater workers in the republic, later transformed into the Theater Workers` Union (1987) [21, p.32]. The role played by these creative unions in the field of development of culture, their participation in cultural construction, the principal position, the functions, the literary and artistic direction they have taken and defined, the development course they have taken, and the activity they have carried out in this regard have been strengthened and consolidated (İmage 2).

Image 2. Azerbaijan Creative Unions

Although the ways of creativity, means of expression, fields of activity, the themes they brought to art, the problems they raised, and the levels of craftsmanship of the creative intellectuals who increase their ideological and political levels, and enhance their professional craftsmanship in the creative unions are quite different, the role they play in art – the development of Azerbaijan culture – is undeniable. These creative intellectuals, who differ from each other in their means of expression, beautify art by bringing their interesting thoughts and ideas through "words", "colors", "images" and "performances", who are characterized by their works, images and heroes they created with different but unique and realistic lines, and who are embodied with individual but at the same time progressive and positive elements, are extremely colorful, unique, courageous, realistic, entertaining, thought provoking and educational with the paintings they painted, the fundamental musical works they composed, the beautiful and marvelously animated sculptures they erected, the realistic and artistic – style theater performances they staged, the interesting documentaries and feature films they made, and the diverse roles and performances they played.

Along with the educational, cultural and scientific centers, the creative unions also tried to make their creative contributions to the development of Azerbaijan culture. The creative intellectuals are such a social and professional force that they have the power to directly or indirectly influence the spiritual and moral world, the ideological and political education, the formation of a modern and realistic worldview of the people, the creation of a perfect and healthy image of a person in society, the strengthening of civic position, the cultivation of a conscious attitude to every issue, and the open expression of people`s ideas and opinions through their creativity. The characteristic features of this period were to instill in people a sense of beauty, the formation of high aesthetic taste, the cultivation of the ability to correctly assess the importance and value of historical and architectural monuments and works of art, the understanding of the phenomenon of personality and other characteristics in order to form them as morally rich, harmoniously developed individuals [22, p.67].

The creative intellectuals develop literature and art, which are the main factors of moral education, create works of art, enrich them with new and progressive ideas, and introduce our republic to other countries. The working mechanism of the Creative Unions, their organizational activity, the attitude towards talented and creative personnel, bringing the problems posed by society and making it think into fiction and culture, the search for unique solutions to important creative questions facing art and artists by the creative intellectuals in their creativity and works, the search for new creativity, the taking of themes of literary works and art examples from real events encountered in life, etc. undoubtedly played the decisive role in the development of culture [21, p.33 – 34].

The literature and art are one of the most fighter spheres of ideological activity [21, p.36]. İn order for creative intellectuals to create beautiful works of art, it was necessary for them to be artistically literate, to raise their ideological and political level and to develop their

professional skills. In this regard, the theoretical seminars played the important role. In 1961 – 1962, the Union of Artists organized the lectures and seminars at the Republican Political Education House to raise the ideological and political level of artists of the republic, 67 lectures were read on various topics. Such theoretical seminars were held in almost all creative unions. Sometimes associations were also used for this purpose. Such associations mainly represented those working in literary magazines and the newspaper "Literature and Art" [21, p.38].

One of the areas of activity of the Creative Unions was the improvement of the professional skills of creative intellectuals. For this purpose, advanced training, internships, creative seminars, vacations and business trips, competitions, etc. were organized [21, p.45]. The creative vacations of young creative intellectuals meant the creation of new works of art, new creative searches, finding new themes, bringing them to works of art, the creation, demonstration, promotion of rare examples of art that meet modern requirements, etc. The result of the creative vacation of young artists meant the organization of a report exhibition of their works. The young and professional creative intellectuals of the republic were sent on creative vacations to various countries, including regions. The organization of periodic creative vacations of artists, writers, musicians, directors, film workers and other creative individuals played the exceptional role in the development of culture in our country [21, p.52, 55].

One of the main directions of the activity of the Creative Unions is the organization of work with young people, the identification of talented young persons, the organization of seminars and conferences, the establishment of sections, youth studios, youth clubs, associations of young artists and art critics, youth work commissions, holding youth days, various events, organizing exhibitions of young artists, listening to musical works of young composers, etc., meant the raising of the cultural level of young people, and caring for and assisting in the development of culture [21, p.57]. Thus, in 1963, the first republican gathering of cinema mechanics was held in Baku [18]. In 1964, the meeting of film production and distribution workers was held and dedicated to improving film services to the population [20]. As a result of improving the quality of service in the field of cinematography and cinema, taking specific practical measures in this sphere, by 1965 there were 1.340 cinemas and film facilities under the Republican Cinematography Committee [14]. The documentaries, animated films, etc. were shown in genre film clubs operating in some cinemas of Baku. Among them, it is possible to mention the "Cinema distribution` courier", "Kaleidoscope", "Club of movie lovers" and "Heritage" repeated film hall. In 1986, the repertoire of these film clubs included more than 200 works – feature films, documentaries, animated films, etc. [22, p.90]. However, it should be noted that although the importance of scientific – popular, historical – chronicle, chronicle – documentary, and educational films was very great, they were not given enough space in the development of cinematography and the creative process. At the same time, there was a need to apply the achievements of modern science and technology during the production of motion pictures.

The demonstration of the activity of creative intellectuals and their works can be considered a kind of creative report on the work done in the field of development of culture. In this regard, the exhibitions of works by artists, composers, playwrights, theater and cinema figures were organized, photo stands and photo albums reflecting their activity were prepared, their works were included in radio and television programs, performances were prepared, films were shown, the importance of the roles they play was studied and analyzed by art historians and literary critics. The various new works, theater performances, documentaries and feature films were presented to the audience for discussion, their objective, progressive ideas and opinions were taken into account [22, p.90].

İn 1960, four brigades consisting of actors from the Opera and Ballet Theater, the Young Spectator Theater, and members of the Theater Society were organized to deliver reports on themetic topics at the various institutions and organizations of the republic [22, p.91].

The Azerbaijan Creative Unions were engaged in theoretical and practical activities in the field of development of culture, forming their creative and organizational work. One of the most important tasks facing the creative intellectuals represented in the creative unions, associations and societies was to constantly work and struggle for the creation of works of high artistic quality. For to raise the ideological and artistic level of works of art, the disputes, discussions, round tables, competitions and reviews of works were organized. The creative and organizational work carried out by the unions was one of the main field of their activity. The deep scientific research of the active theoretical and practical activities of the Azerbaijan Creative Unions in the republic was conducted by Doctor of Historical Sciences, Professor Nisbet Mehdiyeva. The talented historian, the great expert in this field, the researcher of the current issues of Azerbaijan culture, the activity of creative intellectuals in the field of development of culture, and the role, place and activity of Creative Unions in the field of culture in the 1960 – 1980s of XXth century, Professor Nisbet Mehdiyeva played the exceptional role in the study of creative intelligentsia and creativity issues with her fundamental scientific works. Professor Nisbet Mehdiyeva`s textbook " The activity of the Azerbaijan Creative Unions in the field of mass propaganda (1960 – 1980s)" (1990) [22], the book "The cultural relations of the Azerbaijan Creative Unions (1960 – 1980s)" (1991) [23] and the monograph "The activity of the Azerbaijan Creative Unions in the field of development of culture (1960 – 1980s)" (2014) [21] are the fundamental scientific and research works dedicated to the activity of the Azerbaijan Creative Unions and the role played by creative intellectuals in the field of development of culture in the republic. The researcher notes that the struggle for the writing of works of high artistic quality occupied a central place in the activity of creative unions [21, p.76]. The Writers` Union discussed the issue of creating a human image in works of art, the reflection of the friendship of peoples in Azerbaijan literature, the introduction of humanist ideas into

fiction and other actual issues at its mobile plenums in 1970 and 1971 [21, p.78,79]. The role of literary and artistic criticism in raising the ideological and artistic level of literary and artistic works was also emphasized here [21, p.79]. This was engaged by the criticism departments of the Writers` Union bodies. The Writers` Union paid the special attention to solving the creative problems, preparing and listening to creative reports [21, p.80, 81].

The creative intellectuals during this period constantly worked and fought for the literary and artistic works they created to be a perfect example of creativity, artistically and morally perfect, with a solid composition, based on a correct plot line, complete human images, and colorful means of expression [21, p.87]. They tried to ensure that theatrical performances and films not only educated the audience with their content, but also reflected the novelty of form, the richness of human character, and the characteristic features of life. At the same time, the creative intellectuals tried to avoid stereotypes, primitiveness, standard themes, to apply courageous searches, innovation, new genres and the importance of solving creative problems in their works of art [21, p.105]. The role of creative intellectuals in the development of Azerbaijan culture was very specific and diverse, and in the 60 – 80s of the XXth century it passed the very successful and at the same time glorious way, rich in creative struggle. The role played by the creative intellectuals in the development of all spheres of culture greatly enriched, developed Azerbaijan culture and led to the creation of unique examples of art, rich in progressive – realistic features, based only on accurate facts and to some extent on the creative imagination of the artist.

Conclusion

The culture is an integral part of every nation. The nation that does not develop its culture cannot understand itself and cannot take its rightful place among other nations. The creative intellectuals are innovative, progressive worldview, mature and creative individuals who constantly work in the various spheres of this culture, develop and enrich it, create and promote new and perfect examples of art, literature and works of art, are in search of new creativity, and bring new thoughts and ideas to art. Guided by the ideas of realism, they enrich these themes with a bit of artistic imagination and, by combining them, create incomparable works, paintings, drawings, sculptures, beautiful performances, interesting films, fundamental musical works, etc. literary and artistic masterpieces. Each work is a set of specific themes, a single plot line, a unity of images, an event that the writer or artist intended and wanted to describe. This unity connects images, embodies elements together, and connects each episode with the general essence of an event or problem. The creative intellectuals express this unity with their talent and skills, creating unique examples of art. The culture owes for its development to the great labor, boundless talent, skill and ability, and creative craftsmanship of these creative intellectuals.

In the 60 – 80s of the XXth century, the creative intelligentsia of Azerbaijan did the great work with their scientific and artistic activities, participating in the solution and research of actual problems of culture. The role of the creative intelligentsia in the development of Azerbaijan culture was quite diverse and singled out for its spec-ial activity and relevance in the 60 – 80s of the XXth century. The extensive activity of creative intellectuals during this period has been carefully, conscientiously and great responsibly examined in the scientific works and fundamental scientific research works of our valuable researchers and has found their scientific solution.

Azerbaijan culture is proud of its creative intellectuals. They have done a great deal in very short period of time and have managed to develop each sphere of culture separately. The culture is like iron, as it is worked, read, written, performed, and understood, it develops, becomes perfect, embodies the progressive thoughts and ideas, and always pleases refined tastes. In this regard, the role of creative intellectuals in the field of development of Azerbaijan culture in the 60 – 80s of the XXth century is undeniable and occupies one of the most worthy places. The talented researchers of our country, conscientiously and responsibly investigating this honorable role and activity of creative intellectuals, demonstrated the intellectual position and highly appreciated the great and honorable work of intellectuals – creative intelligentsia, and dedicated the fundamental works to this valuable activity.

References:

1. *Azerbaijan National State Archive of Literature and Art*, fund 254, list 2, case 122, sheet 41.
2. *Azerbaijan National State Archive of Literature and Art*, fund 254, list 2, case 132, sheet 26.
3. *Azerbaijan National State Archive of Literature and Art*, fund 254, list 2, case 151, sheet 175.
4. *Azerbaijan National State Archive of Literature and Art*, fund 254, list 2, case 158, sheet 65.
5. *Azerbaijan National State Archive of Literature and Art*, fund 344, list 3, case 227, sheet 53.
6. *Azerbaijan National State Archive of Literature and Art*, fund 344, list 3, case 261, sheets 67 – 69.
7. *Azerbaijan National State Archive of Literature and Art*, fund 344, list 3, case 262, sheet 6.
8. *Azerbaijan National State Archive of Literature and Art*, fund 344, list 3, case 272, sheet 17.
9. *Azerbaijan National State Archive of Literature and Art*, fund 344, list 3, case 282, sheets 31, 159.
10. *Azerbaijan National State Archive of Literature and Art*, fund 344, list 3, case 282, sheet 32.
11. *Azerbaijan National State Archive of Literature and Art*, fund 361, list 2, case 53, sheets 6 – 7.
12. *Azerbaijan National State Archive of Literature and Art*, fund 444, list 1, case 49, sheet 14.
13. *Azerbaijan National State Archive of Literature and Art*, fund 444, list 1, case 50, sheets 1, 3.
14. *Azerbaijan National State Archive of Literature and Art*, fund 444, list 1, case 212, sheet 89.
15. *Azerbaijan National State Archive of Literature and Art*, fund 486, list 1, case 165, sheets 80 – 81.
16. *Azerbaijan National State Archive of Literature and Art*, fund 486, list 1, case 165, sheets 102 – 103.
17. *Azerbaijan National State Archive of Literature and Art*, fund 486, list 1, case 189, sheets 9 – 10.

18. *Azerbaijan National State Archive of Literature and Art*, fund 501, list 1, case 120, sheets 47 – 48.

19. *Azerbaijan National State Archive of Literature and Art*, fund 501, list 6, case 195, sheet 80.

20. *Azerbaijan National State Archive of Literature and Art*, fund 501, list 7, case 262, sheet 36.

21. Mehdiyeva, N. (2014). *The activity of the Azerbaijan Creative Unions in the field of development of culture (1960 – 1980s).* Baku: Mutarjim.

22. Mehdiyeva, N. (1990). *The activity of the Azerbaijan Creative Unions in the field of mass propaganda (1960 – 1980s).* Baku: Baku University Publishing House.

23. Mehdiyeva, N. (1991). *The cultural relations of the Azerbaijan Creative Unions (1960 – 1980s).* Baku: Azerneshr.

24. *Party History Institute and Party Archives*, fund 1, list 397, case 52, sheet 23.

25. *Union of Cinematographers of Azerbaijan. From Congress to Congress (1976 – 1980).* Baku: 1980.

JURISPRUDENCE

ART LAUNDERING: CULTURAL ASSETS IN CROSS-BORDER TRANSACTIONS AND SANCTIONS-RESISTANT WEALTH

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Abstract
This article examines how cultural assets, particularly works of art and antiquities, are used within cross-border transactions to launder wealth and evade sanctions. The unique structural characteristics of the global art market — high value, confidentiality, subjective pricing, and portability — make it a vulnerable conduit for illicit financial flows. Drawing on international legal frameworks, comparative national approaches, and enforcement responses, the article assesses existing regulatory gaps and proposes legal reforms to mitigate risks without undermining legitimate trade and cultural exchange.

Keywords: Art, art laundering, money laundering, global market, international law

1. Conceptual Framework: Art Laundering and Sanctions Evasion

Art laundering refers to the exploitation of art transactions to integrate illicit or sanctioned wealth into the legitimate economy. Illicit actors can mask the source, ownership, and movement of funds through inflated sale prices, anonymous intermediaries, shell companies, and repeated resale across jurisdictions.

The market's opacity — low transparency, high reliance on intermediaries, and limited regulatory reporting — exacerbates this risk.

In *Money Laundering and Sanctions Evasion Using the Art Market* (Basel Institute on Governance, 2022), Andrew Dornbierer underscores that the structural characteristics of the art market—its reliance on intermediaries, fragmented regulation, subjective valuation practices, and entrenched norms of confidentiality—generate systemic vulnerabilities that are uniquely attractive to actors seeking to obscure beneficial ownership and circumvent sanctions regimes. He emphasizes that unlike traditional financial institutions, art market participants have historically operated outside comprehensive AML/CFT frameworks, enabling high-value transactions to occur with limited customer due diligence and minimal scrutiny of source of funds. Dornbierer further argues that the cross-border mobility of cultural assets, particularly when combined with freeports, offshore corporate vehicles, and private sales, facilitates the layering and integration stages of money laundering while simultaneously allowing sanctioned individuals to store and transfer value beyond the effective reach of financial sanctions. Importantly, the study situates these risks within a broader regulatory asymmetry: while global banking standards have tightened under FATF guidance, the art sector remains unevenly regulated, creating a form of market displacement whereby illicit capital migrates toward less supervised asset classes. This analysis supports the contention that cultural property must be understood not merely as an object of heritage protection, but as a financial instrument embedded within transnational risk networks. [1]

2. Sanctions-Resistant Wealth and Art

Sanctions-resistant wealth involves assets and financial structures that allow individuals or entities subject to sanctions to preserve and move value outside the reach of enforcement mechanisms. Cultural assets, particularly those transacted privately or stored in freeports, can be strategically used to evade regulatory detection and to preserve economic value when financial channels are restricted. Hufnagel and King's comparative legal analysis elucidates how the recent incorporation of art market intermediaries into anti-money laundering (AML) regimes reflects both the structural vulnerabilities of the sector and the broader regulatory challenges of aligning cultural commerce with financial crime controls. They observe that measures such as the European Union's Fifth Anti-Money Laundering Directive have extended compliance obligations to art dealers, galleries, and auction houses, yet this expansion arises largely in response to longstanding concerns that the opacity and informality of art transactions create fertile conditions for laundering illicit proceeds. The authors further demonstrate that the application of AML criminal law and preventive requirements in practice can expose legitimate commercial actors to significant legal risk, including potential prosecution for routine business activities, underscoring the tension between effective deterrence and disproportionate regulatory burden. Moreover, the uneven implementation of AML controls across jurisdictions — particularly in contexts where high-value dealers have traditionally operated outside of formal supervisory frameworks — underscores a persistent gap in global oversight. This unevenness, they argue, not only complicates enforcement but may inadvertently incentivize the migration of illicit capital through less regulated art market channels, thereby amplifying risks related to cross-border wealth concealment and sanctions evasion. [2]

3. The Legal Landscape

From a treaty-law perspective, the international regulatory framework addressing cultural property and financial crime remains conceptually fragmented. The 1970 UNESCO Convention, formally the *Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property*, establishes a preventive regime centered on state cooperation, restitution, and the safeguarding of cultural heritage; however, its normative architecture is primarily directed toward the protection of cultural patrimony rather than the suppression of financial crime or asset-concealment schemes. [3] The Convention does not impose anti-money laundering (AML) obligations, nor does it require due diligence standards analogous to those applicable within the regulated financial sector. By contrast, the Council of Europe's *Convention on Laundering, Search, Seizure and Confiscation of the Proceeds from Crime* (CETS No. 141, Strasbourg Convention) mandates the criminalization of money laundering and facilitates transnational cooperation in asset tracing and confiscation. [4] Yet, while expansive in scope, it operates in a sector-neutral manner and does not specifically address the structural vulnerabilities of art markets or cultural asset transactions.

At the level of global standard-setting, the Financial Action Task Force (FATF) has acknowledged the susceptibility of the art and antiquities trade to money laundering and terrorist financing risks, particularly given the sector's opacity, high-value transactions, and cross-border mobility. [5] Nevertheless, as of 2025, art market participants are not comprehensively embedded within the FATF's designated non-financial businesses and professions (DNFBPs) framework in the same systematic manner as lawyers, accountants, or real estate agents. This regulatory asymmetry contributes to uneven implementation across jurisdictions and leaves residual compliance gaps that may be exploited for sanctions evasion and cross-border wealth concealment.

4. Key Vulnerabilities in Art Markets

One of the most persistent structural vulnerabilities of the art market lies in its entrenched culture of confidentiality and its historical reliance on private, intermediary-driven transactions. As Don Thompson observes, the contemporary art market operates through networks of dealers, advisors, auction houses and collectors in which discretion is not merely incidental but constitutive of market practice; pricing negotiations, identity of buyers and sellers, and transaction structures are frequently shielded from public disclosure. [6] This opacity is further reinforced by the routine use of agents and corporate vehicles, which may legally separate beneficial ownership from formal title. A second vulnerability arises from the inherently subjective and socially constructed nature of artistic valuation. Unlike commodities traded on regulated exchanges, artworks lack standardized pricing mechanisms; value is shaped by reputation, scarcity narratives, curatorial endorsement, and speculative demand. [7] As Thompson demonstrates, pricing in the high-end art market often reflects symbolic capital and brand positioning rather than intrinsic material worth, resulting in significant price elasticity even within short timeframes. [8]

This indeterminacy of value creates opportunities for deliberate overvaluation or undervaluation in order to facilitate illicit financial integration

5. Policy Recommendations

The integrity and traceability of provenance should be significantly enhanced through the systematic development of comprehensive digital registries and secure record-keeping mechanisms. Such systems provide verifiable documentation of ownership and transactional history, limiting opportunities for artworks to function as opaque repositories of wealth detached from accountable oversight. By establishing clear and enduring chains of custody, these measures not only bolster market transparency but also facilitate the identification of suspicious activity before assets are mobilized across jurisdictions.

Complementing internal record-keeping, the strengthening of cross-border cooperation is essential to effectively monitor and recover cultural property implicated in illicit financial schemes. Coordinated networks connecting national regulators, customs authorities, and international law enforcement bodies enable timely information exchange, unified investigative responses, and the enforcement of asset recovery measures. This integrated approach ensures that high-value cultural goods cannot easily evade detection or enforcement, thereby reinforcing both regulatory compliance and the broader integrity of transnational art markets.

As global sanctions regimes evolve, cultural assets in the art market remain a notable avenue for laundering wealth and evading enforcement. Robust legal frameworks, informed by international cooperation and balanced regulation, are essential to mitigate these risks without undermining the sector's cultural and economic contributions.

References:

1. Dornbierer, A. (2023). *Money laundering and sanctions evasion using the art market* (Basel Institute on Governance Quick Guide 29). Basel Institute on Governance. ISSN 2673-5229

2. Saskia Hufnagel and Colin King, 'Anti-Money Laundering Regulation and the Art Market' (2020) 40(1) *Legal Studies*, pages 131-150

3. UNESCO, *Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property* (adopted 14 November 1970, entered into force 24 April 1972) 823 UNTS 231

4. Council of Europe, *Convention on Laundering, Search, Seizure and Confiscation of the Proceeds from Crime* (adopted 8 November 1990, entered into force 1 September 1993) ETS No 141 (Strasbourg Convention).

5. Financial Action Task Force (FATF), *Money Laundering and Terrorist Financing in the Art and Antiquities Market* (FATF 2023).

6. Don Thompson, *The $12 Million Stuffed Shark: The Curious Economics of Contemporary Art* (Palgrave Macmillan 2008).

7. Olav Velthuis, *Talking Prices: Symbolic Meanings of Prices on the Market for Contemporary Art* (Princeton University Press 2005).

8. Don Thompson, *The Orange Balloon Dog: Bubbles, Turmoil and Avarice in the Contemporary Art Market* (Palgrave Macmillan 2017)

MEDICAL SCIENCES

THE ROLE OF PROPER NUTRİTİON İN THE PHARMACOKİNETİCS OF THE BODY

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Abstract
Proper nutrition is a fundamental factor in maintaining human health and improving life quality. It affects metabolism, organ functions, mood, work capacity, and the prevention of chronic non-communicable diseases. Nutrient balance, meal timing, and dietary diversity play critical roles in the pharmacokinetics of medications. This article explores the influence of correct nutrition on health, its impact on drug absorption and metabolism, the role of vitamins and minerals, and dietary recommendations for different age groups. Special attention is paid to stress, hydration, and the compatibility of foods for optimal digestion and well-being.

Keywords: Proper nutrition, metabolism, pharmacokinetics, vitamins, minerals, diet

Proper nutrition is one of the fundamental conditions for maintaining health. It is no coincidence that the majority of diseases are associated with metabolic disorders caused by improper nutrition. Proper nutrition ensures quality of life by supporting health, mood, work capacity, metabolism, and the full functioning of various organs and systems, while also helping to prevent many non-communicable diseases (NCDs).[1,2].

As far back as ancient times, Hippocrates said, “You are what you eat,” and also stated, “Let food be thy medicine, and medicine be thy food.” The great scholar Avicenna (Ibn Sina) recommended practices such as warm baths, massaging the body with oil, light exercise, walking, horseback riding, reading, a diet based on plant foods and dairy (especially goat and mare’s milk), red wine in moderation, mild laxatives, and a calm lifestyle as means of prolonging life [4]. Certain cultures, such as the Zerbels and Abkhazians, attributed longevity to specific dietary habits, including consuming eggs, chicken, leafy and wild plants, low-calorie foods, and herbal teas, while Leonardo da Vinci noted that excessive calcium intake could accelerate aging [5;6;7].

The quality of nutrition significantly impacts human health and life. Experience shows that neglecting dietary principles is one of the most common mistakes. Daily food intake should meet the body’s vitamin and mineral needs. Overconsumption of any nutrient can lead to adverse effects. Excessive consumption of high-energy foods, saturated fats, sugar, or salt, combined with insufficient intake of fruits, vegetables, and whole grains, disrupts metabolism and contributes to chronic non-communicable diseases such as obesity, diabetes, cardiovascular diseases, hypertension, stroke, and certain cancers, reducing work capacity and increasing premature mortality [2;9;10].

A monotonous diet reduces appetite, diminishes the pleasure of eating, and negatively affects dietary habits, ultimately harming the body. Regularly consuming a variety of foods—including fruits, vegetables, meat and dairy products—promotes both physical health and mental well-being. For proper cellular function, the body requires a balanced intake of carbohydrates, fats, proteins, vitamins, and minerals. Periodic rest is also essential, as the intestinal walls can accumulate between 3 and 25 kilograms of waste.[11].

In many cases, when prescribing medications, it is important to choose an appropriate diet to maintain drug bioavailability and avoid undesirable side effects. Improper nutrition during illness can affect treatment outcomes, worsen organ-specific conditions, and lead to relapses. For example, excess sodium in the diet raises blood pressure, animal fats contribute to atherosclerosis, and poorly digestible foods can exacerbate gastrointestinal disorders [9].

An improper diet can inactivate medications, as seen when calcium-rich foods (e.g., curd, kefir, milk) are consumed with tetracyclines, forming indigestible complexes. Meanwhile, consuming vegetables and fruits can regulate bowel function, provide essential macro- and microelements, phytoncides, essential oils, and aromatic compounds, and support digestive

enzyme activity and lactation. Potassium deficiency can be corrected with dried apricots, raisins, beets, apples, pumpkins, and dried fruits. Iron-rich foods (strawberries, apricots, apples, beets, pomegranate) combined with ascorbic acid enhance the effectiveness of anti-anemic drugs. Watermelon is recommended for urinary tract and kidney inflammation, while low-calorie vegetables (cabbage, carrots, radish, cucumber, tomato, eggplant, pumpkin) reduce caloric intake, prevent cholesterol absorption, facilitate its elimination, and regulate bowel movements [2; 11]. .

Selecting proper therapeutic nutrition can significantly enhance drug bioavailability. Excessive consumption of processed, packaged, refined, fried, high-fat foods and carbonated sweet drinks causes additional strain on the digestive system and other organs. Healthy nutrition requires not only high-quality, ecologically clean foods but also adherence to proper dietary schedules and lifestyle habits. The digestive system aids in nutrient absorption and interacts directly with the excretory system. Eating while standing, rushing, or eating too quickly can cause digestive problems.

Proper chewing and mastication are essential in a healthy diet. Thoroughly chewing and moistening food with saliva aids digestion and reduces energy expenditure for the digestive process. Proper chewing increases saliva production, which supports stomach enzyme activity. Consuming cold foods and drinks can weaken enzyme function, while excessively hot foods and beverages can stop enzyme secretion and damage the stomach. A proper diet supports healthy digestion, mental well-being, and physical vigor. Eating too quickly disrupts digestion and may lead to overeating, as satiety is controlled by the brain rather than the stomach. Reducing food portion size by 1.5–2 times can improve health outcomes. Daily meals should be divided into 3–6 small portions, with adjustments for longer daylight in summer.

Caloric intake is critical. Consuming more calories than needed leads to fat accumulation, obesity, and the development of related diseases. Nutritional requirements should be adjusted according to lifestyle: physically active individuals burn more calories, while sedentary individuals require carefully planned meals with controlled energy content to maintain optimal health [10].

When planning the daily diet of individuals engaged in mental work, the following guidelines are followed. Physical labor requires a higher food intake. If an adolescent is experiencing rapid growth in height and body weight, the quantity of food should be increased accordingly. Maintaining balance and appropriate portion sizes is impossible without adhering to a structured eating schedule. From a physiological perspective, consuming meals four times a day is considered optimal. Dinner should be taken at least two hours before sleep [11].

In terms of energy distribution, the daily intake should be divided as follows: breakfast – 25%, lunch – 35%, snack – 15%, and dinner – 25%. The total daily energy intake is approximately 2400–2500 kcal, with 1200–1400 kcal from carbohydrates, 720–810 kcal from fats, and 400–460 kcal from proteins. In a moderately restricted diet, the average daily intake is: protein 70–80 g, fat 80–90 g, and carbohydrates 300–350 g. Animal protein should account for at least 50% of total protein intake, with half of this amount coming from dairy protein. One-fourth of the daily fat intake should come from butter, one-fourth from vegetable oils, and the remaining half from fats naturally present in foods and culinary fats (e.g., margarine). Sugar should constitute approximately 15% of total carbohydrate intake, and at least 25% of carbohydrate consumption should come from potatoes, vegetables, and fruits (about 80–100 g). Additionally, the daily intake should include 2 g of essential fatty acids and 25 g of dietary fiber.

Regarding meal composition, breakfast should avoid processed meats (sausage, salami, ham), canned foods, fruit juices (especially sour orange or grapefruit), coffee, overly sweet foods, and cold products, as these are not compatible with a healthy diet. Optimal breakfast foods include plenty of water, hot tea, cheese, a small amount of butter, honey, milk-based cereals (oatmeal, buckwheat, etc.), eggs (boiled, scrambled, omelet, etc.), and whole-grain bread. Lunch should include soups and main dishes made from meat, fish, poultry (occasionally), mushrooms, and vegetables. Dinner should consist of light snacks, salads, yogurt, and milk products. Meals consumed after 6 p.m. or late at night are poorly digested during sleep and can lead to bloating, fatigue, weakness, and nausea the next day.

One of the major factors disrupting proper nutrition is stress. Stress causes significant metabolic changes. For instance, during fat metabolism, mobilization of fat from adipose tissue occurs, increasing triglycerides and free fatty acids in the blood, which are then burned for energy. Cholesterol synthesis in the liver increases 2.5-fold, and excessive fatty acids accumulate in organs, leading to hepatic fat infiltration. Carbohydrate metabolism is also affected: glycolysis and glycogenolysis accelerate, insulin secretion from pancreatic β-cells decreases (hypoinsulinemia), blood glucose increases, and conversion of glucose to fatty acids accelerates, resulting in fat deposition.

Stress increases the body’s demand for vitamins 2–3 times, particularly B-complex vitamins. Vitamin B1 participates in acetylation of choline in cell phosphatides. Vitamin B2 prevents adrenal hyperplasia caused by stress [10]. Vitamin B6 deficiency impairs myelin lipid synthesis, and the requirement for vitamin E increases. Stress also increases the need for minerals, especially potassium and copper. During stress, consumption of meat and meat products, sugar, and grain-based foods (various types of bread, pastries, excluding buckwheat and oats, cakes, biscuits, chocolates) negatively affects overall health. **Antistress nutrients** include amino acids (methionine, tryptophan, tyrosine, glutamine), dietary fiber (cellulose, pectin), vitamins (B1, B2, B6, PP, E), and minerals (Ca, K, Fe, Cu, Mn) [11; 12].

When selecting a diet, it is essential to consider a person’s age. Improper nutrition can accelerate premature aging, making it particularly important to carefully plan the diets of elderly individuals. Older adults should take into account potential digestive difficulties, maintain consistent meal times, and regulate portion sizes and caloric intake—especially fats, carbohydrates, sweets, and other high-starch foods [13].

It is recommended to increase the intake of biologically active substances, such as vitamins, trace elements, phosphatides, and amino acids, and to enrich meals with natural anti-sclerotic compounds. Long gaps between meals should be avoided. Elderly individuals should minimize consumption of rice, pasta, legumes, cream, sour cream, salty fatty cheeses, egg yolks, sorrel, spinach, sugar, confectionery, fatty ice cream, chocolate, and creamy desserts. Conversely, to maintain health, they should prioritize breads and baked goods (wheat and rye bread, bran porridge, cookies with soy flour or seaweed), low-fat dairy products, lean meats, poultry, and fish, as well as 2–4 lightly cooked eggs per week.

Among all foods, water is the most essential for health. Water is vital for life and as important as the air we breathe. Rich in minerals, water plays a crucial role in the body's biochemical reactions. It helps regulate body temperature, supports digestion, and facilitates the elimination of harmful substances. Daily fluid intake should be at least 2–3 liters. Drinking a glass of water upon waking is beneficial. Water should be consumed about 30 minutes before meals, but not during or immediately after eating. Developing the habit of drinking 2–3 liters of plain water daily—initially sipping 30 grams every half hour during the first month—is considered an effective therapeutic approach. In cases of fever, pain, mental or physical fatigue, or stress, one should refrain from eating, consume food only when hungry, and drink a glass of lukewarm water 10–15 minutes before meals as a regular practice [14].

Drinking water during meals or immediately afterward is not recommended, as water leaves the stomach within 10–15 minutes, washing away gastric juices and disrupting digestion. It is better to drink water 30 minutes after fruits, 2 hours after starchy foods, and 4 hours after protein-rich foods.

Salt intake should be reduced in the diet, and completely avoided in cardiovascular diseases. Table salt contains only two trace elements—sodium and chloride—whereas sea salt contains 64 trace elements beneficial to the body. Onion, garlic, sorrel, and radish can serve as alternatives to table salt.

Proper digestion occurs only when the diet is correctly structured, making it essential to understand which foods can be combined. Professor Herbert Shelton identified incompatible food combinations to prevent digestive conflicts. He recommended that protein-rich foods—such as nuts, meat, eggs, and other protein sources—should not be eaten simultaneously with carbohydrate-rich foods like bread, potatoes, pastries, or sweet fruits. For example, eggs, fish, milk, and cheese can be consumed at one time, while bread, porridge, or noodles can be eaten at another [15].

Carbohydrate-rich foods should not be eaten with acidic foods; for example, bread, potatoes, legumes, bananas, and dates should not be combined with tomatoes, lemons, oranges, kiwis, tangerines, feijoa, pineapple, and other acidic fruits. Fats should not be consumed together with proteins—such as cream, butter, sour cream, or vegetable oils with meat, eggs, cheese, or nuts—because such combinations inhibit gastric secretion. Similarly, acidic fruits like oranges, lemons, tangerines, feijoa, kiwis, sour apples, sour plums, tomatoes, pineapples, and cherries should not be eaten with protein-rich foods like meat, cheese, nuts, or eggs.

Starchy foods should not be combined with sugars—such as jam, fruit, buttered sugar, syrup, porridge, or potatoes—as this leads to fermentation in the intestines. Starch-rich foods should be eaten separately, as combining two types of starchy foods (e.g., potatoes or porridge with bread) interferes with digestion. Fats should not be eaten simultaneously with proteins, as they slow gastric juice secretion. Milk is an exception: after being transformed into yogurt, curd, ayran, whey, or cheese, it can be consumed more safely, since the fat in milk temporarily inhibits gastric juice but is digested in the duodenum rather than the stomach. Foods consumed simultaneously with milk are not properly digested, as the stomach does not secrete enzymes in response to milk.

Therefore, for proper nutrition, it is crucial to avoid monotonous, incompatible, or repetitive combinations. Meal planning should be done in advance, taking into account which foods, vegetables, and fruits will be consumed throughout the week. Proper nutrition also plays a vital role alongside pharmacotherapy in preventing and treating diseases. Improper nutrition contributes to the development of many pathologies and can significantly influence the course of treatment. Consequently, ensuring a diet that is ecologically clean, high-quality, and properly scheduled is one of the most important aspects of modern health preservation and disease prevention.

References:

1. World Health Organization. Healthy diet. WHO; 2020.

2. Willett WC, Stampfer MJ. Current concepts: Diet and health. N Engl J Med. 2013;368:544–553.

3. Hu FB. Dietary pattern analysis: A new direction in nutritional epidemiology. Curr Opin Lipidol. 2002;13:3–9.

4. Hippocrates. On Diet Ancient Greece, 400 BC.

5. Avicenna. The Canon of Medicine. 1025 AD.

6. Kiple KF, Ornelas KC. *The Cambridge World History of Food. Cambridge University Press, 2000.

7. Leonardo da Vinci. Notebooks on nutrition and health. 15th century.

8. Slavin JL, Lloyd B. Health benefits of fruits and vegetables. Adv Nutr. 2012;3:506–516.

9. Mozaffarian D, et al. Global sodium consumption and health outcomes. BMJ. 2014;349:g4966.

10. Power ML, Schulkin J. The Evolution of Obesity. Oxford University Press, 2016.

11. Gropper SS, Smith JL. Advanced Nutrition and Human Metabolism. 7th ed. Cengage, 2020.

12. Institute of Medicine (US). Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride*. National Academies Press, 1997.

13. Popkin BM, D'Anci KE, Rosenberg IH. Water, hydration, and health. Nutr Rev. 2010;68:439–458.

14. Shelton H. Food Combining Made Easy. 1951.

15. Lutz TA, Woods SC. Overview of the physiology of appetite regulation. Physiol Behav. 2012;106:27–33.

EFFECTS OF VITAMIN D ON MUSCLE FUNCTION AND PERFORMANCE: A REVIEW

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Abstract

Vitamin D insufficiency is frequent in the general population. Meta-analyses of randomized controlled trials (RCTs) have shown a decreased risk of falls in elderly treated with vitamin D supplements, which may be due to an improved neuromuscular function in vitamin D-replete subjects. In most observational studies, vitamin D status correlates positively with muscle strength and postural stability. However, as physical activity is associated with vitamin D status as well as muscle strength, effects of vitamin D status on muscular health can only be assessed properly in RCTs. A systematic search was performed and 16 RCTs on the effects of treatment with vitamin D on muscle function were identified. All except one of the studies were performed in subjects above 50 years of age. Baseline 25-hydroxyvitmin D (25OHD) levels were below 50 nmol/l in 11 studies. Plasma 25OHD levels increased significantly in all studies. In seven studies, a beneficial effect of vitamin D treatment was documented on muscle strength of the lower legs, body sway, and/or physical performance. Identified studies were heterogeneous with regard to most aspects including indices measured. No obvious characteristics delineated studies showing beneficial effects from studies showing no effects. Only a few investigators reported the statistical power of measurements performed. In conclusion, evidence from RCTs do support an effect of vitamin D supplements on muscle strength and function in the elderly, but more studies showing a lack of an effect have been published than studies showing beneficial effects. There is a major lack of data on possible effects in younger subjects.

Keywords: elderly, muscle strength, vitamin D

Introduction

For many years, vitamin D has been known to be of importance to musculoskeletal health. It is well known that severe deficiency causes rickets (in children) and osteomalacia ('softening of the bones') in adults. Symptoms include paresthesia in hands and feet as well as aching muscles and bones. Findings include muscle weakness with particularly proximal myopathy causing difficulty getting up from a chair without using arms and by walking on stairs. Gait disturbance occur and gait is often characterized as waddling ('penguin gait'). The clinical feature of the myopathy associated with severe vitamin D deficiency is supported by findings from *in vivo* and *in vitro* experimental studies showing histological and electrophysiological changes in severe vitamin D deficiency. The vitamin D receptor (VDR) is expressed in the cell nuclei of muscle cells and vitamin D has been shown to affect muscle cell contractility. The number of VDRs decreases with age, which supposedly is a contributing factor to reduced muscle strength in the elderly. In addition to a direct effect of vitamin D on muscle cells, vitamin D deficiency causes secondary hyperparathyroidism (SHPT) which may also impair muscle function.

Vitamin D is either ingested from food or synthesized in the skin during sun exposure. In most subjects, sun exposure is the primary determinant of vitamin D status, accounting for 80–90% of the vitamin D body stores. Cholecalciferol (vitamin D3) is synthesized in the skin and found in fatty fish and mammals, whereas ergocalciferol (vitamin D2) comes from yeasts and plants. Vitamin D supplements may contain either vitamin D2 or D3. Previously, the two vitamin D metabolites were considered to have an equal potency, but recent studies have suggested that vitamin D2 may be inferior to vitamin D3 in the treatment of vitamin D insufficiency. Vitamin D2 and D3 are both hydroxylated primarily in the liver to 25-hydroxyvitamin D (25OHD) and subsequently in the kidneys (and different peripheral cells) to become the active vitamin D metabolite, 1,25-dihydroxyvitamin D (calcitriol), which acts on the VDR.

Vitamin D status is usually assessed by measuring plasma 25OHD levels. Plasma 25OHD levels below 50 nmol/l are considered as a state of insufficiency, although an increasing number of studies suggest that levels above 80 nmol/l are needed to ensure an optimal vitamin D status. Vitamin D deficiency is defined as plasma 25OHD levels below 25 nmol/l, and levels below 12 nmol/l are considered as a state of severe deficiency which may cause frank osteomalacia and severe proximal myopathy.

In vitamin D insufficiency, muscle function and physical function may be impaired before clinical or biochemical signs of bone disease are evident. An increased risk of falls in elderly subjects with low vitamin D levels have been documented in several studies and

randomized controlled trials (RCTs), and meta-analyses of RCTs have shown a reduced risk of falls in elderly treated with vitamin D supplements. Most likely, this is due to an improved neuromuscular function in response to vitamin D supplementation. Similarly, associations between vitamin D status and muscle strength, body sway and physical performance have been investigated in a large number of cohort and cross-sectional studies with most, but not all, studies showing the beneficial effect of vitamin D status on measured indices. However, interpretation of results from observational studies is difficult, as plasma 25OHD levels, physical activity and muscle strength are closely interrelated. In several studies, physical activity has been shown to correlate positively with vitamin D status which most likely is due to the fact that physically active subjects spend more time outdoors in the sun and accordingly have a higher endogenous vitamin D synthesis than physically inactive subjects. In addition, physical activity improves muscle strength. Although most observational studies have adjusted statistically for potential interactions of physical activity and vitamin D status on muscular strength, residual confounding may exist and accordingly results from RCTs are imperative in order to draw valid conclusions on the effects of vitamin D status on muscle function.

The aim of the present paper is to review systematically the current state of knowledge on the effects of vitamin D on muscle strength and performance, based on results from individual RCTs.

Type and duration of interventions

In most studies, vitamin D3 has been administrated orally as either a daily, weekly or monthly dose. In most studies, an average daily dose of between 400 and 1200 IU of vitamin D3 was studied, whereas two studies used substantially higher average doses administrated either weekly (2000 IU/day) or monthly (3700 IU/day). In five studies, vitamin D2 has been administrated as either a single intramuscular or oral dose, as two doses administrated 10 weeks apart, or as a daily oral dose. The doses of vitamin D2 used have varied widely. In nine studies, vitamin D3 has been administrated in combination with a daily calcium supplement and in these studies calcium alone (without vitamin D) has been used as a comparator.

In the WHI study, follow up was performed after an average of 7.1 years, whereas time to follow up has varied from 2 to 24 (average 8) months in the other 15 studies.

Effects of interventions on plasma 25OHD and PTH levels

In all but one study, the effect of treatment on plasma 25OHD levels has been reported, showing a significant increase in 25OHD levels in vitamin D treated subjects compared with controls .

Baseline plasma 25OHD levels were below 50 nmol/l in 11 of the included studies. In 13 studies, the effects of treatment on plasma PTH levels was reported showing either significantly decreased levels or no effects compared with the controls. Vitamin D3 has been co-administrated with calcium in four of the five studies showing decreased PTH levels, as well as in four of the studies showing no effects on PTH levels. No apparent differences exist between studies showing or not showing effects on plasma PTH levels regarding dose of vitamin D administrated or baseline plasma 25OHD levels. However, none of the studies using vitamin D2 showed effects on plasma PTH levels.

Effects on muscle function

Overall, seven studies showed a positive effect of vitamin D treatment on muscle strength, postural sway and/or physical performance, whereas nine studies found no evidence of effects on measured indices.

Effect on muscle strength

Effects of vitamin D on muscle strength was evaluated in 12 studies. In most studies, a dynamometer/strain gauge system was used to measure maximal voluntary isometric muscle strength; Hajj Kenny *et al.*2003;.

Lower legs isometric muscle strength, as assessed by using a strain gauge system, was evaluated in eight studies. Two studies showed an improved isometric muscle strength in response to treatment. Accordingly, in response to 6 months of treatment with 800 IU/day vitamin D3, Pfeifer and colleagues found significantly increased quadriceps strength compared with placebo. Similarly, Moreira-Pfrimer and colleagues found significantly improved maximal isometric strength of hip flexors and knee extensors in vitamin D3-treated subjects compared with placebo.

In addition to using a strain gauge system, effects of vitamin D treatment have been evaluated in a Japanese study in terms of a physical therapist (blinded to treatment allocation) assessing muscle strength using the British Medical Research Council scale. The study included women with poststroke hemiplegia and showed that compared with placebo, 2 years of treatment with 1000 IU/day vitamin D2 caused a significantly improved strength of the gluteus maximus and iliopsoas muscles on the intact side.

Effects of vitamin D treatment on hand grip strength have been evaluated in five studies, none of them showing significant effects.

No obvious differences exist between the studies showing or not showing effects in terms of characteristics of included subjects or effects of treatment on plasma 25OHD or PTH levels.

Conclusions:

In conclusion, several lines of evidence support an effect of vitamin D on muscle function and findings from RCTs have shown beneficial effects of vitamin D supplementation in the elderly. However, an effect is not universally present as more papers showing a lack of an effect have been published than papers showing beneficial effects. Explanations for the discrepant results are not obvious, as no general characteristics seem to separate studies showing beneficial effects from studies showing no effect of an improved vitamin D status. Further studies should try to replicate findings from the studies showing beneficial effects with predefined sample size calculations in order to assure a proper statistical power. Moreover, as low vitamin D levels are common in the general population, more studies are needed in younger subjects in order to assess potential harmful effects of vitamin D insufficiency on neuromuscular health in subjects below the age of 50 years

References:

1. Ahmed W., Khan N., Glueck C.J., Pandey S., Wang P., Goldenberg N., et al. (2009) Low serum 25 (OH) vitamin D levels (<32 ng/mL) are associated with reversible myositis-myalgia in statin-treated patients. Trawsl Res 153: 11–16

2. Annweiler C., Beauchet O., Berrut G., Fantino B., Bonnefoy M., Herrmann F.R., et al. (2009a) Is there an association between serum 25-hydroxyvitamin D concentration and muscle strength among older women? Results from baseline assessment of the EPIDOS study. J Nutr Health Aging 13: 90–95

3. Annweiler C., Schott-Petelaz A.M., Berrut G., Kressig R.W., Bridenbaugh S., Herrmann F.R., et al. (2009b) Vitamin D deficiency-related quadriceps weakness: Results of the Epidemiologie De l'Osteoporose cohort. J Am Geriatr Soc 57: 368–369

4. Baczynski R., Massry S.G., Magott M., Belbessi S., Kohan R., Brautbar N. (1985) Effect of parathyroid hormone on energy metabolism of skeletal muscle. Kidney Int 28: 722–727

5. Bellido T., Boland R. (1991) Effects of 1,25-dihydroxy-vitamin D3 on phosphate accumulation by myoblasts. Horm Metab Res 23: 113–116

6. Bischoff H.A., Borchers M., Gudat F., Duermueller U., Theiler R., Stahelin H.B., et al. (2001) In situ detection of 1,25-dihydroxyvitamin D3 receptor in human skeletal muscle tissue. Histochem J 33: 19–24

7. Bischoff H.A., Stahelin H.B., Dick W., Akos R., Knecht M., Salis C., et al. (2003) Effects of vitamin D and calcium supplementation on falls: A randomized controlled trial. J Bone Miner Res 18: 343–351

8. Bischoff H.A., Stahelin H.B., Tyndall A., Theiler R. (2000) Relationship between muscle strength and vitamin D metabolites: Are there therapeutic possibilities in the elderly? Z Rheumatol 59(Suppl. 1): 39–41

9. Bischoff H.A., Stahelin H.B., Urscheler N., Ehrsam R., Vonthein R., Perrig-Chiello P., et al. (1999) Muscle strength in the elderly: Its relation to vitamin D metabolites. Arch Phys Med Rehabil 80: 54–58

10. Bischoff-Ferrari H., Conzelmann M., Stahelin H., Dick W., Carpenter M., Adkin A., et al. (2006) Is fall prevention by vitamin D mediated by a change in postural or dynamic balance? Osteoporos Int 17: 656–663

11. Bischoff-Ferrari H.A., Borchers M., Gudat F., Durmuller U., Stahelin H.B., Dick W. (2004a) Vitamin D receptor expression in human muscle tissue decreases with age. J Bone Miner Res 19: 265–269

ROLE OF VITAMIN D IN MITOCHONDRIAL HEALTH

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Abstract

Vitamin D, a secosteroid hormone, appears to have significant beneficial effects on various physiological systems, including the musculoskeletal system. Vitamin D assists in the regulation of numerous critical biological functions and physiological processes in humans, including inflammation, oxidative stress, and mitochondrial respiration, and is also linked to cardiac diseases. It is also reported that vitamin D plays a central role in molecular and cellular mechanisms, which reduce oxidative stress, and tissue damage and regulate cellular health. On the other side, hypovitaminosis D reduces mitochondrial activity and increases oxidative stress and inflammation in the body. Hypervitaminosis D increases the prevalence and severity of cellular damage. It has also been reported that vitamin D is involved in many functions of the reproductive system in human and critically play an important role in the reproductive tissues of women and men. Its role is very well defined, starting from female menarche to menopause, pregnancy, and lactation, and finally in male fertility. Hence, the appropriate amount of vitamin D is necessary to maintain the normal function of cell organelles. Based on recent studies, it is understood that vitamin D is involved in the biological activities of mitochondria in cells, especially in cardiomyocytes. In this review, we emphasized the role of vitamin D in mitochondrial respiration, which could significantly influence heart health and human reproduction.

Keywords: Vitamin D, mitochondrial dysfunction, oxidative stress, cell damage, inflammation, cardiac diseases

Introduction

Vitamin D is fat-soluble, linked to bone metabolism, and is well-known for its essential role in bones and skeletal muscle health (Halfon et al., 2015(1)). Vitamin D is present in bread, milk, fatty fish, mushrooms, and dietary supplements. As we know that there are two main forms of dietary or supplemental vitamin D. These are vitamin D2 and D3. Vitamin D2 is derived from plants, while vitamin D3 comes from animals (fatty fish or sheep's lanolin). Both the forms are significant for overall vitamin D levels. The biological roles of vitamin D are very well defined. Cholecalciferol (known as vitamin D3) is bound to serum vitamin D-binding protein (DBP). For the biological activation of vitamin D, two-step enzymatic pathways are necessary. These are involving 25-hydroxylase of the liver and 1α-hydroxylase (CYP27B1) of the kidney and extra-renal tissues. The majority of the functions are mediated by the VD receptor (VDR), which is a ligand-dependent transcription factor. This transcription factor is primarily localized in the nuclei of target cells. VDR works as a mediator for the genomic action of the biologically active hormone calcitriol ($1,25(OH)_2D3$). Calcitriol is an active form of vitamin D, which is produced by the hydroxylation of 25(OH)D in kidneys under the regulation of parathyroid hormone (PTH) and serum calcium. This form acts as an inducer for the transcription of more than 900 genes (Minghetti and Norman, 1988(2)). VDR receptor is widely distributed over various tissues and organs including skeletal muscles, parathyroid glands, and the reproductive tissues.

Vitamin D levels of 50 nmol/L were found to be insufficient in various clinical investigations and were linked to muscular atrophy and faintness (Tagliafico et al., 2010 (3); Van Langenberg et al., 2014(4)). When exposed to ultraviolet B rays, the human skin converts 7-dehydrocholesterol to vitamin D (Jäpelt and Jakobsen, 2013(5). The *CYP P450* gene family has been expanded to include numerous genes that play pivotal roles in vitamin D activation and degradation (*CYP2R1*, *CYP27B1*, and *CYP24A1*). Vitamin D initially hydroxylated in the liver predominantly by the CYP2R1 enzyme to produce 25-hydroxyvitamin D and then in the kidneys by another enzyme, CYP27B1, to produce 1α,25-dihydroxyvitamin D, which is the hormonally active form (Griffin et al., 2003; Bouillon et al., 2008; Saponaro et al., 2020).

Vitamin D is attached to its serum carrier, vitamin D binding protein (DBP) in the bloodstream. DBP is a highly polymorphic protein that has at least 120 different isoforms. Gc1f, Gc1s, and Gc2 are the three primary isoforms that have sparked the most interest. Their structural differences have an impact on DBP function, which is linked to a large number of clinical aspects. Studies confirm that polymorphism of specific DBP isoforms leads to a lower level of circulating DBP (San-

tos et al., 2019). Serum calcium levels have been reported to be normal in patients with low levels of circulating DBP. The primary role of DBP is to keep a stable reservoir of circulating extracellular vitamin D metabolites in place. DBP is more effective in this role than albumin due to its stronger affinity for vitamin D metabolites, even though both DBP and albumin are filtered into urine and retrieved by megalin.

Under normal physiological conditions, 1α,dihydroxyvitamin D binds to its nuclear receptor, the vitamin D receptor (VDR), and then to a retinoid X receptor (RXR), forming a VDR-RXR heterodimer that interacts with regulatory elements in the genome and regulates the transcription (Haussler et al., 1997). VDR is a transcription factor that has been shown to influence the expression patterns of many genes (Khammissa et al., 2018). The interaction of 1α,25-dihydroxyvitamin D with its intracellular receptors is also known to affect vitamin D-dependent gene transcription and activation of vitamin D-responsive elements and trigger various second messenger systems (Gil et al., 2018). Vitamin D deficiency raises the risk and severity of several diseases, including obesity, insulin resistance, type 2 diabetes, hypertension, pregnancy issues, memory difficulties, osteoporosis, autoimmune diseases, malignancies, and systemic inflammatory illnesses (Garcia-Bailo et al., 2011; Berridge, 2017; Szymczak-Pajor et al., 2020).

The Endocrine Society recommends a daily dose of 400 IU of vitamin D for children aged 0 to one year and 600 IU for children aged one to eighteen years. The Society advises 1500-2000 IU for men and women over 18 years old, including nursing and pregnant women whose newborns are not getting enough vitamin D (Endocrine Society, 2017). Vitamin D deficiency/insufficiency is a public health problem because it is independently connected with a greater risk of all-cause mortality. Vitamin D3 therapy with a daily dose of 500 U reduced the frequency of respiratory infections by two-thirds in patients with 25-hydroxyvitamin D levels less than 20 ng/ml, which typically leads to impaired absorption of vitamin D. Vitamin D sufficiency, a serum 25-hydroxyvitamin D level of at least 30 ng/mL reduced the risk for adverse clinical outcomes in patients with COVID-19 infection (Maghbooli et al., 2020). Hypovitaminosis D was associated with a decline in muscular function and performance and increased disability (Berridge, 2017; D'Amelio and Quacquarelli, 2020). Vitamin D supplementation has been shown to boost muscle strength and speed in aged people (Halfon et al., 2015; Berridge, 2017). Vitamin D supplementation has been linked to a lower risk of falls due to direct effects on muscle cells (Ramasamy, 2020; Wilson-Barnes et al., 2020). On the other hand, excessive vitamin D levels might have harmful effects, such as kidney stones, renal impairment, malignancy, and possibly some indications of cardiovascular disease (CVD), especially when combined with a high calcium intake (Brouwer-Brolsma et al., 2013).

The research focus on vitamin D has expanded beyond its recognized classic bone health benefits, including diabetes and cardiovascular, neurological, pulmonary, renal, and liver illnesses. Yet, several contradictory discoveries continue to emerge (Stokes and Lammert, 2016). However, some controversies and uncertainties still exist in certain aspects related to a daily dose of vitamin D required in the general population to maintain normal levels of 25-hydroxyvitamin D, supplementation for metabolic bone diseases, ultraviolet-B induced cutaneous production of vitamin D, regulation of 25-hydroxyvitamin D metabolites in the liver, the definition of hypervitaminosis of D, hypovitaminosis in acute illness, requirements of vitamin D during reproduction, cellular and organ activities under vitamin D receptor influence, and possible links between vitamin D and major diseases (Minisola et al., 2019; Giustina et al., 2020). Keeping vitamin D levels in an optimal range allows it to improve several processes while avoiding the complications associated with overdose. The vitamin D fluctuation is widely associated with several diseases, including cardiovascular diseases (Ohsawa et al., 2000; Brewer et al., 2011), cancer (Hammad et al., 2013; Weinstein et al., 2015), immune system disorders (Jeffery et al., 2015; Wang et al., 2017), diabetes (Al-Timimi and Ali, 2013), neuropsychiatric disorders (Kesby et al., 2011) and several other diseases.

Role of vitamin D in mitochondrial function and disfunction

Mitochondria are cell organelles with outer and inner membranes, though the inner membrane forms many folds known as cristae (Ashcroft et al., 2020). The intermembrane space refers to the space between the outer and inner membranes, while the matrix refers to the space within the inner membrane (Ashcroft et al., 2020). The mitochondria produce energy in the form of ATP. The reduction in ATP production is independent of changes in many parameters of mitochondrial machinery, including electron transport system (ETS) complexes I-V, citrate synthase, and cytochrome C oxidase (Ashcroft et al., 2020). After the step-by-step transmission of electrons, the mitochondrial matrix actively pumps hydrogen ions into the intermembrane space. ATP synthase returns protons from intermembrane space to the mitochondrial matrix by passing them across an electrochemical gradient process. ATP is synthesized by coupling proton translocation with phosphorylation of ADP.

In addition to impacting muscle mass and functionality, evidence suggests that vitamin D in skeletal muscles may influence mitochondrial activity. In the case of vitamin D deficiency, mitochondrial respiration diminishes with a reduction in nuclear mRNA and protein (Kim et al., 2014). When 1,25-dihydroxyvitamin D3 was administered to human primary myoblasts, mitochondrial activity improved, and the number of mRNAs encoding mitochondrial proteins increased by almost 80 percent (Ryan et al., 2016). Vitamin D is needed to sustain the functioning of the mitochondrial respiratory chain (Consiglio et al., 2015). The synthesis of the uncoupling protein (UCP), which regulates thermogenesis on the internal mitochondrial membrane, is similarly affected by vitamin D (Abbas, 2017). In particular, the synthesis of ATP is reduced because of the decrease in vitamin D-dependent development of the electron transport chain complex I. Ashcroft et al., (2020) found that VDR is required to maintain mitochondrial respiration at an optimal level in myoblasts

and myotubes (Ashcroft et al., 2020). The reduction in mitochondrial respiration in VDR-deleted myoblasts and myotubes as a result of reduced ATP. Further, vitamin D has no effect on mitochondrial ETC subunit I-V, citrate synthase, or cytochrome-c protein content in VDR-KD myoblasts and myotubes (Ashcroft et al., 2020). The decrease in maximum oxidant ability without any alterations in ETS I-V protein expression was reported in an *in vivo* study with mice deprived of vitamin D (Habib et al., 2020).

Most of the vitamin D research in humans focuses on protein synthesis and breakdown. There is growing evidence that vitamin D supplementation improves mitochondrial density and function (Sinha et al., 2013; Rana et al., 2014). Vitamin D supplementation enhances the balance between synthesis and breakdown of muscle protein, as well as mitochondrial density in an *in vivo* rat model study (Gogulothu et al., 2020). To accomplish the immediate and intensive energy demands during exercise, the muscle stores phospho-creatinine (P-creatinine) (Bouillon and Verstuyf, 2013). P-creatinine is the muscle's inorganic phosphate content. In vitamin D deficient patients, P-creatinine levels were decreased. However, it was restored after vitamin D treatment and exercise in randomized clinical trials (Wagner et al., 2013). The slower rate of energy generation in the mitochondria of skeletal muscle could lead to a loss of muscle strength and a fast feeling of exhaustion during moderate activity (Latham et al., 2021). P-creatinine is broken down during muscle contraction and generates creatine. The P-creatinine system generates a lot of ATPs, which is crucial when metabolic demand is high, such as during intense aerobic exercise, and other metabolic pathways cannot keep up with the need. In essence, P-creatinine fosters the short-term high level of energy needed during intense exercise. Ye et al. (2001) observed a decrease in the P-creatinine /ATP ratio in a pig model of congestive heart failure (Ye et al., 2001). Further, research shows that P-creatinine system damage occurs before contractile dysfunction, which reduces the energy reserve (Ingwall and Weiss, 2004). Vitamin D could reverse P-creatinine fluctuation in contractile function by restoring mitochondrial function, and this could be a potential research target for further investigation. Furthermore, the activation of the vitamin D receptor protein has been confirmed to increase serum creatinine. Concern regarding this fact is that while serum creatinine levels are increased, the glomerular filtration rate decreases. However, a study found results to the contrary. The short-term activation of vitamin D receptors increases serum creatinine levels along with overall creatinine production and generates no detrimental effects on the glomerular filtration rate (Agarwal et al., 2011).

The role of vitamin D receptors in mitochondrial function

Mitochondria are cell organelles with outer and inner membranes, though the inner membrane forms many folds known as cristae (Ashcroft et al., 2020). The intermembrane space refers to the space between the outer and inner membranes, while the matrix refers to the space within the inner membrane (Ashcroft et al., 2020). The mitochondria produce energy in the form of ATP. The reduction in ATP production is independent of changes in many parameters of mitochondrial machinery, including electron transport system (ETS) complexes I-V, citrate synthase, and cytochrome C oxidase (Ashcroft et al., 2020). After the step-by-step transmission of electrons, the mitochondrial matrix actively pumps hydrogen ions into the intermembrane space. ATP synthase returns protons from intermembrane space to the mitochondrial matrix by passing them across an electrochemical gradient process. ATP is synthesized by coupling proton translocation with phosphorylation of ADP.

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The role of vitamin D receptors in mitochondrial function

The ubiquitous nature of VDR suggests the possibility of extensive impacts, prompting further research into the effects of vitamin D in several tissues in the human body (Omdahl et al., 2002). In genomic results, VDR activation in the nucleus leads to cellular differentiation and proliferation (Sirajudeen et al., 2019). Nongenomic effects leading to fast calcium influx within muscle cells could be attributed to a potential transmembrane receptor (Rebas et al., 2017).

1,25-dihydroxyvitamin D controls the oxidative capacity by avoiding substantial changes in the density or amount of ETS protein. A recent study revealed that VDR knock-down (VDR-KD) in myotubes of C2C12 enhances the synthesis of mitochondrial fusion protein optic atrophy 1 (OPA1), which has been proposed as a compensatory strategy for restoring mitochondrial function (Ashcroft et al., 2020). In mitochondria, OPA1 causes internal membrane fusion, resulting in improved mitochondrial oxidative capacity (Kushnareva et al., 2013). The OPA1 protein expression was elevated with 1,25-dihydroxyvitamin D treatment in vitamin D deficient mice with statin-induced myopathy and human skeletal muscle cells (Ryan et al., 2016; Ren et al., 2020). Ricca et al. (2018) studied the *in vitro* function of mitochondria by silencing VDR and reported the enhanced respiratory activity in silenced cells that was associated with increased reactive oxygen generation (ROS). The absence of the receptor eventually led to mitochondrial malfunction and cell death and slowed down cellular proliferation.

Furthermore, a similar study by Ricciardi et al. (2015) found that vitamin D and VDR signaling decreases mitochondrial respiration, serving as an important regulator for many essential bioenergetic metabolic pathways. The ability of vitamin D/VDR to regulate mitochondrial respiration allows the mitochondria to adapt to various metabolic states that arise during times of cell growth, signaling, and proliferation (Silvagno and Pescarmona, 2017). To continue, the study conducted by Silvagno and Pescarmona (2017) found that KO VDR mice have shown deficient calcium absorption leading to hypocalcemia, hypophosphatemia, secondary hyperparathyroidism, osteomalacia, and rickets. The same study also identified VDR as a mitochondrial energy expenditure regulator due to the finding that VDR KO mice have shown higher basal energy expenditure rates and increased levels of energy upcoupling in the form of the electron transport chain in mitochondria. Additionally, VDR KO mice were found to have a debilitating effect on the skin in regards to decreasing the efficiency of the barrier to a host of pathogens via disruption in the processes of lipid composition and secretion that help make the barrier effect.

The VDR protein was discovered with two anti-VDR antibodies, and the mitochondrial VDR disappeared by the VDR gene silencing in immortalized human keratinocytes (Consiglio et al., 2014). VDR localization in mitochondria needs a specific mitochondrial import mechanism involving the import of cholesterol or the export of cytochrome C (Silvagno et al., 2013). It's unclear how mitochondrial VDR affects gene expression, cation control, oxidative function, and tissue-specific activity in platelets or muscles. It also regulates several other nuclear receptors in mitochondria including estrogens, glucocorticoids, and thyroid hormone receptors (Psarra et al., 2006). Mitochondria are generally acknowledged as having a function in forming reactive nitrogen, reactive oxygen species (ROS), and antioxidants. The antioxidants' defense mechanisms were shown to be enhanced in rickets (Doğan et al., 2012). Both metabolic and osteoporosis syndrome is associated with oxidative stress (Manolagas, 2010).

The lack of VDR leads to a decrease in cell proliferation, which is highly required during the cells that acquired higher VDR in the G0 and G1 phases of the cell cycle than in the M phase (Consiglio et al., 2014). Consiglio et al. (2014) found that cancer cells with silenced VDR have decreased the rates of proliferation, leading to the hypothesis that reduced VDR expression could be a possible cancer treatment. Silencing of VDR increased cytochrome C oxidase subunits II and IV transcript. VDR silencing inhibited the mevalonate pathway and histone acetylation levels, which are acetyl CoA-dependent biosynthetic pathways (Consiglio et al., 2014). Inhibiting histone acetylation decreases gene transcription levels, and since acetyl CoA is a key molecule in metabolism, various pathways have the potential to be affected by VDR. These findings suggest that VDR regulates the mitochondrial respiratory chain activity, the acetyl-CoA pathway, the TCA cycle, and biosynthetic pathways of cell development.

Researchers investigated the significance of vitamin D in maintaining the *in vivo* activity of mitochondria by utilizing a known diet-induced vitamin D deprivation model in mice C57BL/6J. The study with a diet-induced vitamin D deficiency model of mice(C57BL/6J) results in reduced mitochondrial respiration in skeletal muscle that could lead to muscle fatigue and performance deficits (Ashcroft et al., 2021). Vitamin D (calcitriol) increases intramyocellular lipid (IMCL) accumulation and oxygen consumption rate, which is driven by mitochondrial complex II in C2C12 myotubes, and this increase is at least partially mediated by a protein, Perilipin 2 (PLIN2) (Schnell et al.,

2019). Kolleritsch et al. (2020) reported that the low cardiac perilipin is linked to reduced mitochondrial fission and could be used to inhibit the emergence of lipotoxic cardiomyopathy (Kolleritsch et al., 2020). An increase in myocardial lipid storage and decreased cardiac performance were observed after myocardial infarction in people with PLIN2 deficiency(Mardani et al., 2019).

Conclusion

There is significant evidence that lack of vitamin D contributes to the development of heart failure (Zittermann et al., 2006). Vitamin D promotes mitochondrial homeostasis and prevents protein oxidation, lipid peroxidation, and DNA damage caused by oxidative stress. Autophagy, mitochondrial malfunction, inflammation, oxidative stress, epigenetic modifications, DNA abnormalities, and calcium and ROS signaling changes are all known to be regulated by vitamin D. The excess vitamin D may lead to calcification. Therefore, proper dosages of vitamin D are required to treat patients in clinics. In several patients, low blood levels of 25-hydroxyvitamin D lead to increased mortality, especially sudden cardiac death and coronary illness. In this review, we emphasized the potential role of vitamin D in critical biological processes and the functions of explorations of the biological components in mitochondrial-associated cardiac diseases.

In summary, vitamin D supplementation in humans plays a significant role in supporting mitochondrial health and regulating cardiac disease progressions. Detailed mechanical inquiries are necessary to light the manifestation of vitamin D in mitochondrial function and cardiac health.

References:

1. Halfon M, Phan O, Teta D. Vitamin D: a review on its effects on muscle strength, the risk of fall, and frailty. Biomed Res Int. 2015;2015:953241. doi: 10.1155/2015/953241.

2. Minghetti PP, Norman AW. 1, 25 (OH) 2-vitamin D3 receptors: gene regulation and genetic circuitry. FASEB J. 1988;2:3043–3053. doi: 10.1096/fasebj.2.15.2847948.

3. Tagliafico AS, Ameri P, Bovio M, Puntoni M, Capaccio E, Murialdo G, et al. Relationship between fatty degeneration of thigh muscles and vitamin D status in the elderly: a preliminary MRI study. Am J Roentgenol. 2010;194:728–734. doi: 10.2214/AJR.09.3130.

4. Van Langenberg DR, Gatta PD, Hill B, Zacharewicz E, Gibson PR, Russell AP. Delving into disability in Crohn's disease: dysregulation of molecular pathways may explain skeletal muscle loss in Crohn's disease. J. Crohn's Colitis. 2014;8:626–634. doi: 10.1016/j.crohns.2013.11.024.

5. Van Langenberg DR, Gatta PD, Hill B, Zacharewicz E, Gibson PR, Russell AP. Delving into disability in Crohn's disease: dysregulation of molecular pathways may explain skeletal muscle loss in Crohn's disease. J. Crohn's Colitis. 2014;8:626–634. doi: 10.1016/j.crohns.2013.11.024.

THE USE OF HAIR TRANSPLANTATION TECHNIQUES TO TREAT OF SECONDARY CICATRICIAL ALOPECIA

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ВИКОРИСТАННЯ ТЕХНІКИ ПЕРЕСАДКИ ВОЛОССЯ ДЛЯ ЛІКУВАННЯ ВТОРИННИХ РУБЦЕВИХ АЛОПЕЦІЙ

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Abstract

The aim of the study was to investigate the clinical effectiveness of autologous transplantation technologies by follicular unit extraction (FUE) and direct hair implantation (DHI) in patients with secondary cicatricial alopecia.14 patients (6 men and 8 women) were examined, aged 21 to 49 years, patients with a defect area of 5 to 420 cm2. Causes of cicatricial alopecia were burns (4 patients), trauma (5), surgery (5). FUE and DHI hair transplantation technologies were used. The Global Aesthetic Improvement Scale (GAIS), objective patient satisfaction and hair engraftment percentage were used to evaluate the results. From 171 to 2990 hair follicular units were removed and transplanted. Patients were observed for 12 months with the following treatment options: FUE (12), FUE in combination with DHI (2). The average hair survival rate was 84.1%. GAIS score: complete improvement (6 cases), obvious improvement (4), partial improvement (4), no improvement (0) and deterioration (0). Patient satisfaction scores: very satisfied (5), mostly satisfied (7), dissatisfied (2). The conducted studies allowed to conclude that the assessment of the results of treatment should be carried out no earlier than twelve months after the last transplant. The method of autologous hair transplantation can be successfully used for the treatment of patients with secondary cicatricial alopecia. After the operation, natural patterns of hair growth, rapid restoration of the hair cover and high patient satisfaction (86%) were observed.

Анотація

Метою роботи було дослідження клінічної ефективності технологій аутологічної трансплантації шляхом екстракції фолікулярних одиниць (FUE) та прямої імплантації волосся (DHI) у пацієнтів з вторинними рубцевими алопеціями. Були обстежені 14 пацієнтів (6 чоловіків та 8 жінок), у віці від 21 до 49 років пацієнтів з площею дефекту від 5 до 420 см^2. Причини рубцевої алопеції-опіки(4 пацієнти), травми (5), операції(5). Використовували технології трансплантації волосся методом FUE та DHI. Для оцінки результатів використовувалися Глобальна шкала естетичного покращення (GAIS), об'єктивна задоволеність пацієнтів та відсоток приживлення волосся. Було вилучено та пересаджено від 171 до 2990 волосяних фолікулярних одиниць. Пацієнти спостерігалися протягом 12 місяців з такими варіантами лікування: FUE (12), FUE у поєднанні з DHI (2). Середній рівень виживання волосся становив 84,1%. Оцінка за шкалою GAIS: повне покращення (6 випадків), очевидне покращення (4), часткове покращення (4), відсутність покращення (0) та погіршення (0). Результати задоволеності пацієнтів: дуже задоволені (5), переважно задоволені (7), незадоволені (2). Проведені дослідження дозволили зробити висновок, що оцінку результатів лікування необхідно проводити не раніше, ніж через дванадцять місяців після останньої пересадки. Методика аутологічної трансплантації волосся може успішно використовуватись для лікування пацієнтів з вторинною рубцевою алопецією. Після операції спостерігались природні закономірності росту волосся, швидке відновлення волосяного покриву і висока задоволеність пацієнтів (86,2%).

Keywords: Secondary cicatricial alopecia, surgical treatment, hair transplantation, quality of life.

Ключові слова: Вторинні рубцеві алопеції, оперативне лікування, трансплантація волосся, якість життя.

Вступ

Рубцеві алопеції - одна з найбільш гострих проблем сучасної трихології. Поширеність цієї патології становить 5,0–7,3 % від усіх випадків випадіння волосся. На цю групу захворювань припадає 3,2 % всіх консультацій у дерматолога [1,2,3]. Рубцева алопеція спричиняє незворотну втрату волосся та негативно впливає на самооцінку, погіршує якість життя, естетичний вигляд та психологію пацієнта [4]. Залежно від походження рубцеві алопеції можуть бути як спадкового, так і набутого характеру. Набуті рубцеві алопеції поділяються на первинні та вторинні. Серед потенційних причин роз-

витку вторинних рубцевих алопецій (ВРА) виділяють: травматизацію шкірного покриву (опіки, дія випромінювання, травми, операції), лікарські препарати (препарати золота, вакцини), інфекційні агенти (Staphylococcus aureus) [5]. Питання тактики ведення пацієнта та вибору терапії залишається дискутабельним через відсутність достовірних даних щодо етіології та патогенезу ВРА. Наразі в клініці використовуються хірургічні методи лікування: висічення ураженої ділянки, операція пластики клаптем і дермотензія, які потребують кількох етапів, визивають виражений дискомфорт у період розтягування шкіри і мають обмежене застосування, а також являються травматичними і можуть призводити до лінійного рубцевого облисіння [6,7].

Використання технології аутологічної трансплантації волосся, включаючи трансплантацію фолікулярних одиниць (FUT), техніку екстракції фолікулярних одиниць (FUE) та пряму імплантацію волосся (DHI) широко використовуються як малоінвазивний метод лікування гормонозалежної алопеції, але рідко повідомляється про застосування при рубцевій алопеції [8,9,10], тому застосування аутологічної трансплантації волосся у пацієнтів з посттравматичною вторинною рубцевою алопецією потребує подальшого дослідження.

Мета роботи - дослідження клінічної ефективності технологій аутологічної трансплантації шляхом екстракції фолікулярних одиниць (FUE) та прямої імплантації волосся (DHI) у пацієнтів з вторинними рубцевими алопеціями.

Матеріали і методи дослідження

У дослідженні взяли участь 14 пацієнтів (6 чоловіків та 8 жінок), у віці від 21 до 49 років, яких лікували за допомогою аутологічної трансплантації волосся з приводу вторинних рубцевих алопецій у 2024 - 2025 роках. Причини рубцевої алопеції включали п’ять випадків після операцій на голові, чотири випадки після глибоких термічних опіків та п’ять випадків після травм. Критеріями включення були: рубцевий дефект волосся, який існує більше одного року, достатня донорська зона, відсутність рубцевої аномальної гіперплазії, відсутність рубцевої виразки. Критерії виключення були: патологія печінки та нирок, порушення функції згортання крові, вогнищева алопеція (alopecia areata), фронтальна фіброзуюча алопеція. Для окремих пацієнтів, які тривалий час приймали антикоагулянти, їх прийом припиняли за 1 тиждень до операції. За день до операції мили волосся шампунем та підстригали волосся в донорській ділянці. Перед операцією розмічали ділянку операції та оцінювали ступінь дефекту волосся. В залежності від площі рубцевої алопеції, розраховували необхідну кількість одиниць волосяних фолікулів (25-30 графтів на $см^2$). У нашому дослідженні 12 пацієнтів лікували за допомогою технології трансплантації волосся безшовним методом (FUE). За допомогою панча та моторизованої ручки здійснювали забір графів (фолікулярних об’єднань) з подальшим ретельним аналізом та сортуванням графтів за кількістю. Після цього за допомогою лез Sapphire 1,4 мм формувались канали для імплантації графтів у зоні рубцевої алопеції. У 2 пацієнтів проведені операції FUE+DHI (пряма імплантація волосся) при локалізації алопеції на обличчі (борода, брови). Для оцінки ефекту трансплантації волосся пацієнти були обстежені через 12 місяців після операції. Як показники для оцінки використовувалися Глобальна шкала естетичного покращення (GAIS) та об’єктивна задоволеність пацієнтів, що визначалися хірургами та пацієнтами. Для розрахунку відсотку приживлення волосся вибирали три уражені ділянки голови. Відсоток приживлення дорівнював відношенням кількості $FU/см^2$ під час останнього контрольного огляду до кількості $FU/см^2$ одразу після операції, помноженим на 100 %. Всі пацієнти надали письмову інформовану згоду на участь в обстеженні та лікуванні.

Дані вимірювань, що відповідали нормальному розподілу, були виражені як середнє значення ± стандартне відхилення ($\mu \pm \sigma$). Для аналізу даних було використано статистичне програмне забезпечення STATISTICA 6.1 (StatSoftInc., серійний AGAR909E415822FA) и Microsoft Excel (Microsoft Office 2016 Professional Plus, Open License 67528927).

Результати

У дослідженні взяли участь чотирнадцять пацієнтів з площею дефекту від 5 до 420 $см^2$. Було вилучено та пересаджено від 171 до 2990 волосяних фолікулярних одиниць. Пацієнти спостерігалися протягом 12 місяців з такими варіантами лікування: FUE (12 випадків), FUE у поєднанні з DHI (2 випадка), середній рівень виживання волосся становив 84,1 % (таб.1).

Таблиця 1.

Хірургічне лікування та післяопераційне спостереження за 14 пацієнтами з алопецією

№ п/п	Стать	Вік	Площа дефекту ($см^2$)	Хірур-гічний метод	Локалізація	Причина алопеції	Кількість пересаджених юнітів (графтів)	Відсоток приживлення (%)	Рівень задово-леності
1	ж	43	320 $см^2$	FUE	потилиця	операція	2002	92,1%	Переважно задоволена
2	ж	21	210 $см^2$	FUE	тім'я	травма	760	45,1%	Незадоволена
3	ж	35	5 $см^2$	FUE	скроня	операція	140	85.3%	Дуже задоволена
4	ч	20	65 $см^2$	FUE	потилиця	травма	1111	87,6%	Переважно задоволений
5	ж	28	180 $см^2$	FUE	потилиця	опік	638	72,3%	Переважно задоволена
6	ж	44	120 см2	FUE	тім'я	операція	171	96,8%	Дуже задоволена
7	ж	54	220 $см^2$	FUE	тім'я	операція	1020	93,3%	Дуже задоволена
8	ч	25	180 см2	FUE	скроня	травма	715	74,2%	Незадоволений
9	ч	20	145 см2	FUE	потилиця	операція	526	96,4%	Дуже задоволений
10	ч	49	80 см2	FUE+DHI	обличчя	Мінно-вибухова травма	420	93,2%	Дуже задоволений
11	ж	32	230 см2	FUE	лоб	опік	1365	84,5%	Переважно задоволена
12	ж	23	350 см2	FUE	скроні, тім'я	опік	1720	86,5%	Переважно задоволена
13	ч	32	420 см2	FUE+DHI	обличчя	опік	2990	86,2%	Переважно задоволений
14	ч	28	160 см2	FUE	потилиця	травма	1300	84,5%	Переважно задоволений

Жодних очевидних рубців або аномального волосся донорської ділянки не було відзначено (рис. 1).

Рисунок 1. Вторинна післяопераційна рубцева алопеція. Персаджено 2002 графтів. Результат через 12 місяців. Відсоток приживлення – 92,1 %.

Один пацієнт отримав дві трансплантації, тому що одна операція не змогла досягти задовільних результатів і знадобилася друга трансплантація волосся для «загустіння» ділянки (друга сесія виконана через 12 місяців після першої). Оцінка за шкалою GAIS була розділена на п'ять рівнів: повне покращення (6 випадків), очевидне покращення (4 випадки), часткове покращення (4 випадки), відсутність покращення (0 випадків) та погіршення (0 випадків). Результати задоволеності пацієнтів включали: дуже задоволені (5 випадків), переважно задоволені (7 випадків), незадоволені (2 випадки).

Обговорення

Рубцеві алопеції - група запальних захворювань сально-волосяного фолікула, що характеризуються повним руйнуванням пілосебаційних юнітів та незворотною втратою волосся [11]. В структурі даної патології виділяють різні форми захворювання залежно від низки факторів. Залежно від походження рубцеві алопеції можуть бути як спадкового, так і набутого характеру. Причинами генетично обумовлених форм є: вроджена аплазія шкіри, органоїдні невуси, вроджений, бульозний епідермоліз, різні види іхтіозу, синдром фолікулярного кератозу [3,11]. Набуті рубцеві алопеції поділяються на первинні та вторинні. У розвитку первинних рубцевих алопецій провідну роль відіграє деструктивний запальний процес у пілосебаційному юніті, при якому основними мішенями виступають стовбурові клітини в сальноволосяному фолікулі. Патологічний процес супроводжується також прогресуючим відкладенням колагену, втратою сальних залоз. При формуванні вторинних форм рубцевої алопеції основним компонентом виступає вторинне ураження фолікула волосся в результаті залучення його до патологічного шкірного процесу, що призводить до деструкції стовбурових клітин [12]. Трансплантація волосся має такі проблеми, як тривалий час операції, високий ризик кровотечі та погане дотримання режиму. Автори стверджують, що під місцевою анестезією трансплантація волосся значно обмежена, і часто потрібні спеціалізовані лікарні з великим досвідом для проведення операцій під загальною анестезією [3,4,5,6]. У нашому дослідженні всі хворі прооперовані під місцевою анестезією. Ускладнень під час операцій та у післяопераційному періоди не спостерігалось.

Необхідний хірургічний метод слід вибирати відповідно до конкретної ситуації. Нами був обраний метод FUE, який ми застосовували при локалізації рубцевої алопеції на передній лінії росту волосся, а також у скроневій та тім'яній ділянках шкіри голови, особливо для розсіяних рубців після опіків. Метод FUE+DHI ми використовували при локалізації алопеції на обличчі (борода, брови). Було вилучено та пересаджено від 171 до 2990 волосяних фолікулярних одиниць. Пацієнти спостерігалися протягом 12 місяців. Середній рівень виживання волосся становив 84,1 %.

Дослідження показали, що через близьку відстань між реципієнтною ділянкою рубця та донорською ділянкою, запальна реакція під час післяопераційного загоєння рани не сприяє виживанню та регенерації волосся [8,13,14]. Тому ми уникали трансплантації волосся при гострих ранах або ділянках шкіри голови із запаленням. Для пацієнтів із надмірно високими очікуваннями від лікування та поганим кровопостачанням у рубцевих ділянках залисин для досягнення цілей лікування автори рекомендують поєднання інших методів. Наприклад, аутологічну плазму, збагачену тромбоцитами (PRP), можна вводити перед операцією для покращення кровотоку в рубцевих ділянках та під час операції для зменшення пошкодження пересаджених волосяних фолікулів, прискорення загоєння ран та активації сплячих фолікулів. Також можна виконати передопераційну жирову пластику або трансплантацію скроневого фасціального клаптя для збільшення товщини місцевого шару підшкірного жиру, покращення місцевого мікросередовища [15,16]. Застосування плазми, збагаченої тромбоцитами, аутоліпографтингу, стромально-васкулярної фракції клітин є подальшою перспективою наших наукових досліджень.

Висновки

1. Методика аутологічної трансплантації волосся є малоінвазивною, безпечною та надійною і особливо показана для пацієнтів з вторинною рубцевою алопецією. Після операції спостерігаються природні закономірності росту волосся, мінімальна травма, швидке відновлення, висока задоволеність пацієнтів та мінімальні ускладнення.

2. Оцінку результатів операції необхідно проводити не раніше, ніж через дванадцять місяців після останньої пересадки. У тих випадках, коли одна операція не змогла досягти задовільних результатів, друга сесія повинна бути виконана через рік після першої.

Список літератури:

1. Thadanipon K., Suchonwanit P. Measuring Patient Quality of Life Following Treatment for Alopecia. //Patient Preference and Adherence.- 2021.- № 15.- С. 1601–1610. doi: 10.2147/PPA.S282399.

2. Memon R, Avram M. The pros and cons of follicular unit extraction (FUE) versus elliptical donor harvesting (FUT). //J Cosmet Laser Ther.- 2022.- №30.-P.1–3. DOI: 10.1080/14764172.2022.2088795

3. Сулік В.В., Храпач В.В. Місце трансплантації волосся в лікуванні алопеції.//Лікарська справа. -2024.-№2(1171).- С.16-22. DOI:10.31640/LS-2024-2-02

4. Suman D, Kumar Y, Tayal A, Nadikuditi S. The aesthetic reconstruction of post-burn eyebrow alopecia with bilateral superficial temporal artery island scalp flap. //Med Coll Abbottabad.- 2024.-№36(2).- P.459-461. doi: 10.55519/JAMC-02-12771.

5. Alessandrini A., Bruni F., Piraccini B., Starace M. Common Causes of Hair Loss–Clinical Manifestations, Trichoscopy and Therapy.// Journal of the European Academy of Dermatology and Venereology.- 2021.- № 35. С. 629– 640. DOI: 10.1111/jdv.17079

6. Jiping Wang, Jing Liu, Jigang Chen, Yanni Wang. Application of Autologous Hair Transplantation Technique in Children with Cicatricial Alopecia.// Advances in Therapy.- 2023.-№ 40. - P.4024–4031. https://doi.org/10.1007/s12325-023-02581-3.

7. Amouzou K.S., Hissein H. A. , Mokako L .J., Diouri M. Aesthetic Reconstruction Of Post-Burn Eyebrow Alopecia With A Superficial Temporal Island Scalp Flap: A Case Report And Review Of The Literature. //The Annals of Fires and Burn Disaster. -2020.- № 33(4).- P. 329-333. https://pubmed.ncbi.nlm.nih.gov/33708024/

8. Jimenez F., Alam M. , Vogel J., Avram M. Hair transplantation: Basic overview //American Academy of Dermatology. - 2021.- № 85(4).- P.816-817. https://doi.org/10.1016/j.jaad.2021.03.124.

9. Liu L.P., Wariboko M.A., Hu X., et al. Factors associated with early-onset androgenetic alopecia: a

scoping review.// PLoS ONE. - 2024.- №19(3). doi: 10.1371/journal.pone.0299212.

10. Wenjie J, Meng W, Bo W, et al. Correction of undesirable hair orientation after cicatricial alopecia using hair follicle removal and displacement implantation.// Chin J Plastic Surg. – 2020.-№36(10).-P.3. https://pmc.ncbi.nlm.nih.gov/articles/PMC10427550/

11. Yanchao Niu, Ci Ren, Hengli Liao, Zhoufeng Jin, Ling Zhu. Clinical effects of autologous follicular unit extraction transplantation in the treatment of secondary cicatricial alopecia after infections. //Journal of Cosmetic Dermatilogy.-2024.-Vol.23(2)- P.585-590. https://doi.org/10.1111/jocd.15996

12. Baranov I.V., Nor N.M., Slesarenko S.V., Badiul P.O., Tsyhankov K.V. Morphological features of skin scars on the background of treatment with autologous adipocytes. //Medical perspectives.-2020.-№25(3).-P.96-104. https://doi.org/10.26641/2307-0404.2020.3.214822.

13. Collins K., Avram M.R. Hair transplantation and follicular unit extraction.// Dermatol Clin.- 2021.-№39(3).-P.463–78. DOI: 10.1016/j.det.2021.04.003

14. Yanchao Niu, Ci Ren, Zhoufeng Jin, Min Qiao, Xiaoxu Wang, Jian Zhang, Ling Zhu. Autologous follicular unit extraction transplant for postburn cicatricial alopecia: A single-center's retrospective case series. //Journal of Cosmetic Dermatilogy.-2024.-Vol.23(6).-P.2209-2214.
https://doi.org/10.1111/jocd.16237

15. Wang F, Chen Y. et al. Using the follicular unit extraction technique in treatment of male androgenetic alopecia. //BMC Surg.- 2024.-№24(1).-P.358. doi: 10.1186/s12893-024-02655-1.

16. Evin N., Evin S. Camouflage of Postburn Scarring Alopecia Using Nanofat Grafting and Follicular Unit Hair Transplantation.// Plast Reconstr Surg. – 2024.-№154(1).-P.207-215. doi: 10.1097/PRS.0000000000010759.

PEDAGOGICAL SCIENCES

WAYS AND CLASSIFICATION OF DEVELOPING COMPETENCIES IN HISTORY TEACHING

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Abstract
The development of competencies is one of the key objectives of modern education, particularly in the teaching of history. This article examines the theoretical and practical foundations of competency-based history education, the classification of competencies, and effective pedagogical methods for their development. Special attention is given to student-centered learning, 21st-century skills, and innovative teaching approaches such as project-based learning, problem-based learning, and interactive methods. The study emphasizes the role of teachers in fostering critical thinking, creativity, communication, and collaboration skills among students.

Keywords: history education, competencies, critical thinking, student-centered learning, 21st-century skills, pedagogy

One of the main objectives of teaching history is the formation of students' thinking and competencies. According to many educators, acquiring cognitive activity means transforming knowledge into skills. The development of students' competencies depends on several factors. The development of communication skills is closely related to the development of thinking and intellectual abilities. The teacher's speech, textbook texts, historical documents, mass media, and historical literature serve as the main tools for developing students' speech. [2, p10]. During the teaching of history, the competencies formed in students can be conditionally grouped as follows:

1. Analyzing historical sources, identifying the main features and cause-and-effect relationships of historical events, and explaining historical concepts.
2. Systematizing the content of historical knowledge.
3. Relating historical facts within a timeline, preparing chronological and synchronous tables.
4. Explaining historical space, correctly using maps and symbols.
5. Comparing historical events and identifying their similarities and differences.
6. Analyzing historical facts and drawing conclusions.
7. Interpreting historical material and participating in classroom discussions.
8. Using ICT, preparing and presenting various information.
9. Structuring historical material, determining cause–effect relationships, and using historical literature correctly.

A history teacher must first determine the competencies already formed in the class. They should know which skills have been developed in students. Based on this, a differentiated approach is applied. Students of the same age and class may have different competency levels. The formation of competencies is based on mastering certain cognitive skills. To develop a specific competency, the teacher must explain the essence and implementation of the relevant logical operations. Students then perform these logical operations under the teacher's guidance.One of the ways to develop competencies in history teaching is working with historical sources and documents. Through source analysis, students not only gain knowledge about the past but also develop critical thinking and analytical skills.

The sources must be appropriate to students' age and comprehension level. Working with historical sources helps develop research, comparison, and analysis skills. Working with historical sources also develops cognitive skills. Tasks such as identifying the type of source, its period, author, events described, and cause-and-effect relationships contribute to cognitive development. Illustration-based learning also plays an important role in developing competencies. Through illustrations, students learn to exchange ideas, analyze historical processes, and draw conclusions about historical periods. Working with maps plays a special role in competency development. It helps students apply what they see and develop skills such as creating approximate maps. Integration also plays a significant role in developing competencies. Through integration, students develop skills such as analogy, logical reasoning, research, and interdisciplinary comparison. The ability to systematize listened and observed material helps students develop planning skills.

To develop students' ability to compare historical facts and events, comparative tasks should be used. In grades VII and VIII, the development of comparison skills may follow this sequence:

1. Creating tables
2. Comparative analysis of two historical figures, schemes, images, documents, or textbook texts

The teacher's pedagogical mastery and speech play a crucial role in developing competencies. The teacher's speech should be clear, structured, and well-justified so that students can easily understand it. Independent work plays a major role in developing students' competencies. It fosters creativity and the ability to apply learned skills in real life. Independent work also develops research skills, book-handling habits, observation skills, and the ability to understand terminology.

In the modern world, essential competencies for individuals have been identified. The key 21st-century skills include:

1. Critical thinking
2. Creative thinking

3. Collaboration
4. Communication
5. Information literacy
6. Critical evaluation
7. Effective use of technology
8. Flexibility
9. Leadership
10. Initiative
11. Productivity
12. Social skills

One of the methods for developing competencies is the "Incident Method." This method involves solving real-life problems. Students work in groups, analyze incidents, and develop solutions. This method develops problem-solving, logical and critical thinking, evaluation, reasoning, and decision-making skills. Another effective method is the "Who Am I?" technique, which helps students test their knowledge of historical figures in an interactive way and develop questioning and analytical skills. The Socratic Dialogue method also plays an important role. Through dialogue, the teacher identifies correct and incorrect ideas, helping students develop critical thinking. According to the Resolution of the Cabinet of Ministers of the Republic of Azerbaijan dated September 29, 2020, competencies formed during education are referred to as "competences." These include knowledge, skills, habits, and values. [5, p.55]

Classification of Competencies

Cognitive Competencies

- Creativity
- Critical thinking
- Problem-solving
- Decision-making
- Independent learning

Activity-Based Competencies

- Communication
- Cooperation
- Digital literacy
- Information literacy
- Financial literacy

Values

- National identity
- Civic responsibility
- Social responsibility
- Respect for human rights
- Respect for cultural diversity

In conclusion, the development of competencies in history education involves fostering critical thinking, creativity, decision-making, and communication skills. Teaching methods depend on various factors such as class level, lesson objectives, and pedagogical requirements. Teaching approaches can be teacher-centered or student-centered. Modern education prioritizes student-centered learning, where learners actively participate in the learning process. Student-centered learning enables learners to acquire 21st-century skills independently. Teachers guide students and support their learning process.

4C Skills of the 21st Century

1. Critical Thinking
2. Creativity
3. Communication
4. Collaboration [9, 25]

Critical thinking includes analysis, argumentation, classification, comparison, explanation, evaluation, and problem-solving. Creativity includes brainstorming, decision-making, visualization, improvisation, and innovative thinking. Communication includes listening, reading comprehension, speaking, writing, analysis, and information evaluation. Collaboration includes teamwork, leadership, conflict resolution, and time management.

Teaching Methods Supporting 4C Skills

- Project-Based Learning (PBL)
- Problem-Based Learning
- Higher-Order Thinking
- Game-Based Learning
- Technology-enhanced learning

Various platforms such as Kahoot, EdApp, Raptivity, ProProfs, Archy Learning, and others support interactive learning. Low-tech and high-tech teaching methods both play important roles. Research shows that handwritten notes often improve learning retention. Edgar Dale's Cone of Experience demonstrates that interactive learning improves retention and understanding. Interactive learning enhances students' competencies and prepares them for real life by developing 21st-century skills.[6, p.34]

References:

1. Cabinet of Ministers of the Republic of Azerbaijan. (2020). *State Standards of General Education in the Republic of Azerbaijan*. Baku.
2. Abbasov, A. N. (2015). *Modern Teaching Technologies*. Baku: Education Publishing House.
3. Ahmadov, M. (2018). *Methodology of Teaching History*. Baku: Elm və Təhsil.
4. Aliyev, R. (2019). *Fundamentals of Pedagogical Activity*. Baku: Müəllim Publishing House.
5. Huseynova, N. (2020). *Competency-Based Education Model*. Baku: Azerbaijan State Pedagogical University Press.
6. Mammadov, F. (2017). *Interactive Teaching Methods and Their Application*. Baku: Education.
7. Mammadli, S. (2021). *Innovative Approaches in History Teaching*. Baku: Elm Publishing House.
8. OECD. (2019). *The Future of Education and Skills 2030*. Paris: OECD Publishing.
9. Trilling, B., & Fadel, C. (2009). *21st Century Skills: Learning for Life in Our Times*. San Francisco: Jossey-Bass.
10. Anderson, L. W., & Krathwohl, D. R. (2001). *A Taxonomy for Learning, Teaching, and Assessing*. New York: Longman.
11. Dewey, J. (1938). *Experience and Education*. New York: Macmillan.
12. Dale, E. (1969). *Audiovisual Methods in Teaching*. New York: Dryden Press.
13. UNESCO. (2015). *Education 2030: Incheon Declaration and Framework for Action*. Paris.
14. Hattie, J. (2012). *Visible Learning for Teachers*. London: Routledge.
15. Bruner, J. (1966). *Toward a Theory of Instruction*. Cambridge: Harvard University Press.

THE CONCEPT OF EDUCATIONAL LEADERSHIP: ITS ESSENCE AND CORE FUNCTIONS

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Abstract

The article provides a scientific and theoretical analysis of the role of educational management and leadership in the effectiveness of modern education policy. Against the backdrop of globalization, changing labor market demands, and technological development, the complex challenges faced by educational institutions further increase the importance of educational management and leadership. In the article, educational management is presented as a comprehensive process that includes the efficient planning, organization, coordination, control, and evaluation of existing human, financial, infrastructural, and informational resources around a common objective. Leadership, in turn, is explained as a process of interaction between leaders and followers that encourages change. The study groups leadership characteristics, the individual qualities of followers, and situational factors as the main variables affecting leadership effectiveness. At the same time, the differences and interrelationships between the concepts of leadership and management are comparatively interpreted on the basis of theoretical approaches. The article demonstrates that effective leadership and management in educational institutions are of critical importance for creating a high-quality learning environment, increasing organizational productivity, and achieving strategic goals.

Keywords: leadership and its functions, management, quality and models of management, motivation

Introduction

The effectiveness of modern education policy depends directly not only on its proper organization but also on its effective management. Globalization and the changing demands of society and the labor market place highly serious and complex requirements on education systems. Educational management, which is the most important factor in responding to these requirements, has been defined in the literature in various ways in terms of characteristics, behaviors, influence, interaction, and relationships [9, p. 11]. It should be particularly noted that the influence exerted by the leader or administrator in this process may be either direct or indirect. This field of activity constitutes a comprehensive process that involves planning, organizing, coordinating, controlling, and periodically evaluating existing resources namely human capital, financial, infrastructural, and informational resources by concentrating them around a unified goal in order to serve educational objectives [9, p. 9]. The most prioritized aims of activity in this direction are the accurate and purposeful implementation of state education policies and standards, identifying appropriate steps through diagnostic assessment to improve the quality of education, and adapting to and implementing rapidly increasing and constantly renewing technological developments and changes.

Leadership in Education

Leadership is a process that supports the achievement of shared goals by coordinating individual and collective efforts and by ensuring that people understand and agree on what needs to be done and how it should be done [8, p. 6]. This process includes not only efforts to influence and facilitate the current functioning of a group or educational institution, but also efforts to ensure preparedness for future challenges.

Educational management can be considered an interactive process involving important decisions and the participation of many individuals who influence one another. In this process, the person who bears primary responsibility for fulfilling the leadership role is referred to as the “leader,” while the other members are called “followers” [8, p. 7]. Leadership may thus be regarded both as a defined role and as a process of social influence. Some followers or subordinates may assist the primary leader in carrying out leadership functions [5, p. 114]. The distinction between leader and follower roles does not mean that one individual cannot perform both roles simultaneously. Depending on the educational institution and the society in which it operates, a single person may carry out multiple functions; therefore, leadership may be shared or distributed [Derya Kiliçoğlu, p. 10]. For example, while a department head is the leader of their staff, they are simultaneously a follower of higher-ranking administrators within the institution. Shared leadership, in turn, shapes formal and informal leadership positions by involving faculty members in the decision-making process. In other words, this form of management is a shared process aimed at revealing and strengthening individual and collective capacities in order to ensure the effective performance of activities.

In the management of education, through purposeful influence on subordinates, the leader systematically structures and directs activities and relationships within the educational institution or organization. As a result, the leader plays a central role in stimulating people’s motivation, engaging them in processes, effectively directing collective efforts, and contributing to the achievement of goals by increasing organizational effectiveness. At the same time, other studies emphasize

the social and cultural dimensions of leadership, such as shaping reality, jointly constructing goals, embodying values, and promoting change [1, p. 3]. In further research, leadership is explained as a social process that enables people to understand the purposes of the work and activities they perform together and fosters a sense of responsibility toward these activities [3, p. 13]. Rost (1991) defines leadership as a multidirectional influence relationship between leaders and followers aimed at achieving real change based on shared purposes [8, p. 13].

Leadership encompasses both rational and emotional processes. That is, leaders and followers interact with one another on the basis of shared and collective decisions to determine what changes they wish to implement. However, when major changes must be carried out within an organization, authority alone is insufficient to establish commitment, responsibility, cooperation, and influence over others. Leadership is therefore not merely a formal position; rather, it guides through persuasion, motivation, and unification around common goals, based on personal credibility, trust, and communication skills [8, p. 47]. Leaders increase their influence by setting an example, sharing responsibility, and taking the needs of the team into account. Consequently, leadership effectiveness is shaped more by healthy relationships and mutual respect than by formal authority. Thus, leadership can be characterized not only as a set of individual traits but also as a complex process involving interaction, commitment, and change.

One of the general indicators of a leader's effectiveness is the extent to which the performance of a team or educational institution improves and goals are achieved. In this multifaceted process, the leader must organize and coordinate work activities; select goals and strategies; motivate trust and cooperation to achieve objectives; monitor, analyze, and compare internal and external developments; allocate resources purposefully and appropriately to activities and goals; develop subordinates' skills and self-confidence; secure support and cooperation from external educational institutions and organizations; and take into account the beliefs and values of institutional staff, directing activities evenly across all these areas [10, p. 10].

The factors influencing efficiency and productivity in educational management are interdependent in a chain-like manner, with each directly or indirectly affecting the outcome of the others. These factors, referred to as "centers of power," encompass the quantity and quality of organizational output, efficiency (achieving maximum results with minimum resources), as well as the organization's capacity for adaptation and flexibility [3, p. 158]. Accordingly, an educational institution's management performance, management structure, decision-making processes, efficient use of resources, students' academic achievement, the pedagogical competence and professional development orientation of faculty, their satisfaction with education and services, career achievements, and accreditation indicators are all among the factors contributing to the quality of leadership performance.

If the factors that support management in improving the quality of instruction within an institution are systematized, the effects of the following cause-and-effect chain can be analyzed.

Table 1.Leadership Model

The leader's inspiring vision, characteristics, and behaviors
competencies, and initiatives of subordinates
Organizational (workforce) satisfaction
productivity of the organization's training and
The organization's revenues (financial resources)
Situational factors

One effective method for classifying leadership theories and research is to group them based on the analysis of key variables that receive primary attention. The variables that are critically important for understanding leadership effectiveness are generally clustered into three main categories: the personal characteristics of the leader, the characteristics of followers (subordinates), and the situational–contextual factors in which leadership occurs [10, p. 12].

Leader Characteristics

- Traits (personality qualities, values)
- Self-confidence and optimism
- Skills and competencies
- Behavior
- Integrity (behavior consistent with values)
- Influence strategies
- Evaluation of followers

Follower Characteristics

- Traits (needs, values, self-perception)
- Self-confidence and optimism
- Skills and competencies
- Evaluation of the leader's performance
- Trust in the leader
- Level of responsibility and effort directed toward task accomplishment
- Level of satisfaction with work activities and the leader

Situational (Contextual) Characteristics

- Type of organization or educational institution
- Leader's position, formal authority, and power resources
- Structure and complexity of tasks
- Degree of interdependence among tasks
- Organizational culture
- Uncertainty of the external environment

- Level of dependence on external factors
- National and cultural value systems

The leader-related characteristics, skills, and behaviors listed above, as well as the abilities, attitudes, approaches, and motivation levels of subordinates, function as interrelated dependent and independent variables and directly affect the overall productivity and performance effectiveness of educational institutions. The leader's management style, level of emotional intelligence, communication skills, and decision-making approach are among the key factors shaping employees' attitudes toward work, motivation, and professional development. At the same time, the individual characteristics of subordinates, their professional competencies, and their level of alignment with organizational culture play a crucial role in the realization of leadership effectiveness. The interaction among these variables fosters a collaborative environment within educational institutions, enhances the quality of the teaching process, and facilitates the achievement of strategic goals.

In addition, situational or contextual variables—such as organizational structure, available resources, institutional rules, external environmental influences, and changing socio-economic conditions—constitute an integral part of this process and either strengthen or constrain the outcomes of leadership behaviors. Taking these variables into account in a comprehensive and systematic manner is one of the key conditions for achieving desired outcomes, ensuring the sustainable development of educational institutions, and maintaining long-term productivity. In other words, as illustrated in Figure 1, the leader's personal characteristics and skills shape their behaviors. The leader's actions and decisions, as influence variables, affect and reinforce subordinates. As a result of the leader's motivation mechanisms, trust, respect, exemplary behavior, as well as the applied reward and punishment systems, collective reactions and behaviors are formed. Through these interactive and multidirectional influences, organizational performance is shaped and the quality of goal attainment is affected. At the same time, situational (contextual) characteristics indicate external and contextual factors that influence both leader behavior and subordinates' attitudes and behaviors. These factors may include organizational culture, resource availability, the external environment, or the characteristics of assigned tasks. In the proper coordination of educational institutions' activities, the efficient use of human resources, and continuous improvement, the core functions of management play a decisive role.

Planning

Planning, considered the first step of educational management, involves systematic forecasting of an educational institution's future activities and represents a stage of readiness for change in achieving goals. In this phase, objectives and targets are determined and decision-making processes are finalized. As a multi-stage process, planning should be evidence-based and adaptable to situations and conditions. Decisions made at this stage may not always accurately predict future risks and challenges or may yield outcomes different from those expected [6, p. 3].

Organizing

At this stage of management, appropriate task distribution among structures and personnel is carried out, and rights, authorities, and responsibilities are defined. A key principle during structural allocation is the application of coherence, continuity, and systematic organization among activities. At the same time, the formation of creative teams within the organization, increasing employee engagement, and providing suitable infrastructure for effective performance are integral components of this process. Establishing quality assurance and accountability mechanisms, ensuring evidence-based decision-making, and promoting innovative approaches and digitalization to align changes with other steps are of particular importance at this stage [9, p. 184].

Supervision

In research, leadership is generally regarded as the process by which one or more individuals direct group activities toward common goals, influence others, and motivate them to achieve those goals [1, p. 4]. Leadership is not limited to formal authority and organizational directives; it also encompasses additional influence and motivation mechanisms that go beyond this framework [6, p. 24]. There is ongoing debate regarding the distinction between leadership and management. Clearly, an individual may be a leader without being a manager, and a manager without exercising leadership [9, p. 6]. Managers tend to focus on stability, maintaining order, avoiding risk, and achieving short-term results. Leaders, by contrast, emphasize flexibility, innovation, and adaptation, paying attention to both human capital and economic outcomes while analyzing goals and strategies from a long-term perspective. Managers are concerned with how tasks are carried out and guide subordinates accordingly, whereas leaders inspire people to perform better and increase productivity. As noted by Bennis and Nanus (1985, p. 21), "Managers are people who do things right; leaders are people who do the right things" [10, p. 13].

In other words, managers seek to predict and create order while preserving the status quo, whereas leadership seeks to generate organizational change [2, p. 508]. Both roles are important, but problems may arise if an appropriate balance is not maintained. Excessive focus on management may inhibit risk-taking and lead to aimless bureaucracy, where processes, rules, and procedures function only formally and inefficiently. Excessive emphasis on leadership, on the other hand, may disrupt order and produce impractical change. According to Kotter (1990), the importance of leadership and management is partly situational. As organizations grow and become more complex, the importance of management increases, whereas leadership becomes more critical when the external environment is dynamic and uncertain [9, p. 14]. Both roles are essential for leaders in large organizations operating in dynamic environments. Overall, managers ensure the effective implementation of programs by supervising the quality of the teaching process. At the same time, they guide efficient human resource management, appropriate staff selection, proper allocation of financial and material resources, and the development of educational infrastructure.

Implementation

To achieve management objectives, planned actions must be implemented. The implementation stage involves organization, effective communication, identification of human resources, motivation, and management. One of the most critical aspects at this stage is bringing the workforce together, assigning individuals according to tasks, establishing strong coordination in decision-making, and inspiring collaboration to enhance effectiveness. For example, when implementing a new curriculum in an educational institution, leadership must clearly define roles among teaching and administrative staff, establish effective communication mechanisms, and actively involve employees in the change process. This approach contributes to improving instructional quality and achieving institutional goals more efficiently. Additionally, the purpose of changes should be clearly explained to staff, roles and responsibilities should be precisely defined in accordance with each employee's potential, knowledge, skills, and competencies, and active participation in the change process should be ensured. This approach reduces resistance to change and facilitates successful transformation [9, p. 33].

Monitoring and Evaluation

Monitoring and evaluation can be considered alternative expressions for performance tracking and analysis. During the initial stages of an educational institution's activities, deviations from planned goals may occur. Therefore, when activities do not align with plans—such as inefficient resource use or lower-than-expected productivity—quality assurance mechanisms should be established and implemented to ensure and enhance quality. Quality assurance at this stage involves continuous monitoring of activities, assessing outcomes against predefined criteria, and addressing identified problems in a timely manner. At the same time, establishing feedback mechanisms enhances management flexibility and helps minimize potential risks. Thus, quality assurance systems not only ensure alignment with planning but also contribute to improving overall educational outcomes [4, p. 18].

Conclusion

The analyses conducted indicate that effective management and leadership are among the fundamental conditions for the sustainable development of educational institutions in modern education systems. Proper planning, organization, implementation, monitoring, and evaluation in educational management are directly linked to leadership quality. Leaders' personal characteristics, skills, behaviors, and influence strategies significantly affect employees' motivation, professional development, and the formation of organizational culture. At the same time, follower characteristics and situational factors play a critical role in realizing leadership effectiveness.

As emphasized in the article, leadership is not confined to formal authority; rather, it is built upon mutual trust, collaboration, communication, and motivation mechanisms. Maintaining an appropriate balance between leadership and management roles in educational institutions facilitates effective change implementation, enhances teaching quality, and supports the achievement of organizational goals. Ultimately, the leadership model described in the article highlights that the comprehensive and systematic consideration of leadership, followers, and situational variables is one of the key factors ensuring the effective functioning and long-term productivity of modern educational institutions.

References:

1. Bush, T. (2008). Leadership and management development in education.

2. Connolly, M., James, C., & Fertig, M. (2019). The difference between educational management and educational leadership and the importance of educational responsibility. *Educational Management Administration & Leadership*, *47*(4), 504-519.

3. DiPaola, M., & Hoy, W. K. (Eds.). (2015). *Leadership and school quality*. IAP.

4. Ellis, R. *Quality Assurance for University Teaching*. Taylor & Francis/ Ellis, R 1900 Frost Road, Suite 101, Bristol, PA 19007-1598, -1993. 1-335 p.

5. Göksoy, S. (2015). Distributed leadership in educational institutions. *Journal of education and training studies*, *3*(4), 110-118.

6. Kahn, R. L., & Katz, D. (1952). *Leadership practices in relation to productivity and morale* (pp. 612-628). Ann Arbor, MI: Institute for Social Research, University of Michigan.

7. Kilicoglu, D. (2018). Understanding Democratic and Distributed Leadership: How Democratic Leadership of School Principals Related to Distributed Leadership in Schools?. *Educational policy analysis and strategic research*, *13*(3), 6-23.

8. Peter G.Northouse, *Introduction to Leadership: Concepts and Practice, Fourth Edition.*

9. O.H.Rzayev,S.M.Məmmədov, Ş.N.İsmayılov.*Təhsilin İdarə Olunmasının Əsasları.*

10. Yukl, G. (2006). *Leadership in Organizations, 9/e*. Pearson Education India.

THE INFLUENCE OF MUSIC LESSONS ON MATIMATICAL ABILITIES

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ВЛИЯНИЕ МУЗЫКАЛЬНЫХ ЗАНЯТИЙ НА МАТЕМАТИЧЕСКИЕ СПОСОБНОСТИ

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Abstract

The article examines the aspects of influence of musical activities on the development of mathematical abilities of schoolchildren.Connections have been identified between the elegance of musical art and the logical concepts of mathematics, revealed and explored by ancient thinkers.The characteristics of Pythagoras' discovery of the division of harmonies into consonances and dissonances are described.The foundations of Plato's philosophy of musical education and training are outlined.

Common concepts for music and mathematics have been identified: rhythm, fractions, variations, parallelism…Personal observations on the development of children studying in two schools, their differences under the influence of classical music.

Аннотация

В статье рассматриваются аспекты влияния музыкальных занятий на развитие математических способностей школьников. Выявлены связи между стройностью музыкального искусства и логическими понятиями математики, раскрытые и исследованные древними мыслителями. Описаны особенности открытия Пифагора о разделении созвучий на консонансы и диссонансы; основы философии музыкального воспитания и образования Платона. Выявлены общие понятия для музыки и математики: ритм, дроби, вариации, параллельность… Собственные наблюдения за ходом развития детей, обучающихся в двух школах, их отличия под воздействием классичесской музыки.

Научная доказанность эмоциональной развитости детей, одновременно посещающих две школы – общеобразовательную и либо музыкальную, либо художественную, их менее подверженность стрессам…

Keywords: aptitude, mathematical abilities, abstract perception of music, consonans, dissonans, paideia, calogatia.

Ключевые слова: музыкальная одаренность, математические способности, абстрактное восприятие музыки, калокага́тия, паттерны, консонанс, диссонанс.

«Математика и музыка требуют единого мыслительного процесса»
А.Эйнштейн

Введение. Целью этой статьи является сравнительный анализ существующей литературы и научных исследований, посвященных вопросам влияния музыкальных занятий на развитие математических способностей детей разных возрастных категорий. На основании исторических фактов и разработок я провела и собственные исследования, выявив много доказательств о связи музыки и математики. Профессиональные музыканты интуитивно чувствуют пропорционально-симметричные отношения внутри музыкального построения, благодаря абстрактному восприятию музыкальных звуков. Музыкальное построение имеет четкую конструкцию, которая логически обоснована как пространственно-геометрическая форма.

Побудительной мотивацией стали зафиксированные успехи собственной внучки, которая занимаясь музыкой и играя на двух инструментах, очень результативно усваивала математику, особенно когда играла произведения И.С. Баха…

Материалы и методы. Музыка как вид искусства считается одним из мощных средств воздействия на психическое и функциональное состояние человека, в том числе – работу интеллекта через регуляцию эмоционального и соматического фона. [3]

Искусство — единственное свидетельство Вечности. Искусство отметает все виды «духовного опопсовения», порабощения личности. А умение логически мыслить мгновенно раскрывает, «кто есть кто» /М.Казиник/.

Математическая стройность музыкального искусства была раскрыта и исследована древними мыслителями. На заре человеческой цивилизации многие великие умы утверждали, что математика и музыка – две системы мышления, тесно связанные между собой: музыка делает человека более уверенным и эмоциональным, обогащает умственно, способствует духовному развитию, а математика в свою очередь - это инструмент познания, воплощающий порядок и логику.

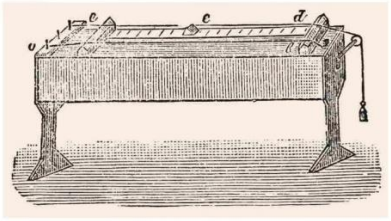
Совпадение музыкальной и математической одаренности сделало эту тему предметом внимания психологов. Им хотелось понять психологические

механизмы, стоящие у истоков музыкально-математической близости. Сущность психологических связей между музыкальными и математическими способностями стала яснее, когда ученые обратили внимание на повышенно-абстрактный характер восприятия музыкантов. Привыкнув замечать пропорционально-симметричные отношения внутри музыкальной формы, привыкнув охватывать в своем сознании разнообразные структуры, не имеющие явных предметных аналогов, музыканты переносят навыки пространственно-геометрического восприятия на реальную действительность.

Математика и музыка – это уникальный инструментарий, описывающий мир. Дети, которые занимаются музыкой, лучше усваивают математику, а кто понимает математику, тому легче изучать музыкальные законы. Занимаясь музыкой, человек занимается математикой. Хороший математик - это всегда хороший музыкант, потому что логика чисел, с которой постоянно общаются математики, связана с логикой развития музыкальных фраз.

Многие авторитетные фирмы и компании, среди которых Microsoft и крупные западные банки, предпочитают сотрудников с музыкальным образованием. Они правы: музыка расширяет и усиливает все духовные и интеллектуальные возможности человека. Музыка настолько многогранна и требовательна ко всем человеческим качествам, что не может быть музыканта, который бы не преуспел в любой сфере деятельности. Музыкант означает лучший: самый дисциплинированный, самый быстрый, самый четкий, самый мыслящий. Широкое внедрение музыкального образования — в детском саду, в школе, в вузе и на любом уровне — позволит каждому человеку максимально раскрыть и умножить все свои способности.

Знание основ музыки приводит к развитию логически точного мышления, наподобие математики. Еще в Древней Греции математика и музыка назывались родными сёстрами, а со времён Пифагора наука о музыке входила в пифагорейскую систему знаний, наряду с арифметикой (наукой о числах), геометрией (наукой о фигурах и их измерений) и астрономией (наукой о строении Вселенной). Пифагор был не только математиком и философом, но и теоретиком музыки. Следуя его теории, числа обладают абсолютной властью над всеми событиями, над всеми живыми существами, а значит, что числа правят музыкой. Именно в музыке Пифагор нашел прямое доказательство своему замечательному тезису: «Всё есть число». Он занимался поисками музыкальной гармонии, поскольку верил в то, что такая музыка необходима для очищения души и врачевания тела и способна помочь разгадать любую тайну.



Изучая высоту звука с помощью монохорда[1] Пифагор обнаружил поразительные вещи. Логичным продолжением открытия Пифагора явилась идея разделения созвучий на консонансы и диссонансы. Без этих понятий музыка европейской традиции не могла бы состояться в том виде, в котором мы ее знаем. Под консонансом понимается созвучие, вызывающее ощущение покоя, гармонии, устойчивости. С математических позиций консонансы выражаются более простым отношением чисел: чистая октава — 1/2, чистая квинта — 2/3, чистая кварта — 3/4. Диссонансы же звучат беспокойно, резко, создают ощущение незавершенности и выражаются более сложным числовым соотношением (например, большая септима — 8/15, малая секунда — 15/16). Следствием незавершенности явилась зависимость – диссонанс использовался только в связке с консонансом, то есть требовал разрешения.

Это открытие потрясло Пифагора: оказалось, что звук и созвучие могут быть описаны простыми числами. Пифагор перенёс числовые соотношения на гармонию Вселенной. Согласно его учению Земля, Солнце, Луна и планеты располагаются на небесных сферах и совершают вместе с ними круговое вращение. Вследствие трения об эфир они издавали музыкальные звуки, которые объединялись в созвучия. Так возникла чудесная мировая музыка или «гармония сфер», без которой мир бы не мог существовать как единое целое. Земная человеческая музыка, по мнению Пифагора, - слабые отголоски музыкальных небесных сфер; она дана человечеству в утешение, и создаёт её тот, кто способен услышать в себе мировую музыку. Пифагор был уверен, что музыка звучит совершенными консонансами (благозвучными интервалами): тон издаваемый Землёй принимался за тонику, сфера Луны звучала квартой, Солнце – квинтой, а звёзды и планеты – октавой.

Наиболее выдающийся вклад в историю музыкальной педагогики внес Платон. Он заложил основы философии музыкального воспитания и образования. Как известно, греческая Paideia[2] была не просто воспитанием и образованием, но введением

[1]Монохорд – (в переводе означает «однострун») простейший инструмент древних греков, состоящего из одной струны, резонаторного ящика и передвижной подставки, с помощью которой можно было изменять длину натянутой струны

[2] (др.-греч. παιδεία — «воспитание детей», от παιδος — «мальчик, подросток») — категория древнегреческой философии, соответствующая современному понятию «образование», определённая модель воспитания; также составная часть слов энциклопедия, педагогика.

в культурную жизнь общества. Целью ее греки считали калокагатию[3], то есть культивирование личности прекрасной и хорошей. Лучшие традиции этой Paideia нашли блестящее воплощение в платоновской Paideia вообще и музыкальной, в частности. Созданная им музыкальная Paideia – замечательный, первый в истории образец целостной философской системы непрерывного музыкального воспитания и образования. [6]

В эпоху Средневековья (с конца XII – начала XIII века) вся совокупность знаний делилась на 7 основных наук: тривиум – начальный курс образования, включавший в себя грамматику, риторику и диалектику; квадриум – повышенный курс светского образования, куда музыка входила так же, как и у пифагорейцев вместе с арифметикой, геометрией и астрономией. Математика не включена в число смежных дисциплин и находится в стороне от музыкального искусства, скорее музыкальное искусство в некоторых своих проявлениях прибегает к использованию математического аппарата.

На ранней стадии музыкознания было открыто, что законы, по которым существует музыкальное искусство, совпадают с описанными математикой законами физического мира. Антон Веберн сказал: «Музыка есть закономерность природы, воспринятая слухом» (XX в.) Г. В. Лейбниц (XVII – XVIII в.в.) сказал: «Когда мы слушаем музыку, наша душа считает, но она не знает, что она считает».

М. Падуанский – ученый и музыкант XIII – XIV в.в. сказал: «Законы Вселенной – законы музыки!». Современная наука разрушила эти красивые фантазии о музыкальном вращении планет. Но гармония целочисленных соотношений продолжает увлекать физиков. Альберт Эйнштейн открыл сходство между колебанием струны и ее частей и атомами испускающими излучение.

Великий немецкий композитор XVIII века И. С. Бах писал церковную музыку. Сам, будучи превосходным органистом-импровизатором, исполнял её. При этом большинство его произведений написаны на сюжеты, взятые из священной книги «Библии». Позднее уже после его смерти музыканты-исследователи выяснили, что многие мелодии композитора имеют цифровые коды - символы, а произведения точно математически просчитаны. Сегодня мы не можем точно сказать, как сочинял композитор свои сочинения, и производил ли при этом математические расчеты. Но остается фактом, что И. С. Бах был выдающимся математиком и гениальным композитором, написавшим много прекрасной музыки.

Исследователь Стэнли Стейнберг из Йельского университета опубликовал аналогичные результаты: ученики восьмого класса, которые занимались игрой на музыкальных инструментах, показали себя гораздо лучшими математиками, чем остальные ученики. Особенно отличились пианисты, которые выиграли по тестовым баллам конкурс по математике. **Ведь, тренируя свои пальчики, они одновременно тренируют и свой мозг!**

Ученые выяснили, что музыка воспринимается нашим мозгом одновременно обоими полушариями. Левое полушарие отвечает за ритм, а правое — за тембр и мелодию. Музыка оказывает влияние на психоэмоциональное и физическое состояние человека. Она пробуждает эмоции и ощущения, влияет на нервную систему, дыхание и кровообращение. У современных ученых есть очень веские доказательства и основания полагать, что прослушивание музыки благоприятно действует на развитие математических и логических способностей у детей. Дело в том, что музыкальное восприятие очень сложно, а сама музыка крайне многообразный «материал». Для того, чтобы услышать и принять музыку, необходимо «поймать» ее на слух, уловить ритм, громкость, сменяющиеся переливы и интонации мелодии. При прослушивании мелодии работают сразу несколько отделов головного мозга. Кит Девлин (известный математик и автор многих книг) в своей книге «Ген математики» указывает, что музыканты и математики одинаково используют для написания абстрактные обозначения тех паттернов (схем-образов), которые существуют в их уме. Опытный музыкант, читая музыкальные символы, сразу же «слышит» в своем уме те звуки, которые эти символы обозначают. Аналогичным образом, математик, читая математические символы, без промедления думает о математических выражениях (логических суждениях), изображаемых этими символами.

Музыка с точки зрения академика В.М.Бехтерева – это «удивительный дар богов», который «…дает больше откровений, чем наука или философия» [3, с.124]. Музыкальный метр, определяющий величину ритмических построений и отражающийся в такте, начинающемся с наиболее сильной доли и завершающемся перед следующей равной ей по силе доле способствует лучшей адаптации и успешному взаимодействию совместно работающих людей, что положительно сказывается на их производительности и качестве результатов труда. В этой связи подчеркивалось «магическое» воздействие «музыки с рельефным ритмом» /марши, танцевальная музыка/ [3, с.121/. Благодаря четкому ритму и строгой соразмерности темпа марш улучшает обменные процессы в организме, освежает и ободряет человека, стимулирует активность при физическом труде. Наиболее сильный эффект достигается при воздействии музыкальными произведениями с более или менее однородной по характеру музыкой, которая способна «развить, поддержать, усилить и по возможности закрепить на продолжительное время определенный эффект» [3, с.113]. Другой стороной использования музыки является возможность успокоить человека, ослабить излишнее возбуждение не только отдельного человека, но и социальных групп.

[3] калокага́тия, др.-греч. καλοκαγαθία, от καλὸς καὶ ἀγαθός — «прекрасный и хороший», «красивый и добрый») — гармоничное сочетание физических (внешних) и нравственных (душевных, внутренних) достоинств, совершенство человеческой личности как идеал воспитания человека.

Есть много понятий, которые являются общими как для музыки, так и для математики. Например:

- **Ритм**. Ему подчиняются и числа (понятие кратности ритмично: числа, кратные трём, укладываются в размер ¾).
- **Дроби**. Длительности звуков основаны на дробях, их легко перевести в числа (половинная – ½.. , четвертная – ¼….).
- **Вариации.** Числа, как и музыкальную тему, можно записать разными способами.
- **Параллельность.** Разные голоса в хоре и партии разных инструментов в оркестре не «пересекаются».

Выводы. Я долгое время наблюдала за развитием детей 10-14-и лет, которые параллельно с учебой в общеобразовательной школе успешно учились в мызыкальной школе. По результатам опросов выяснилось, что в тот период, когда они играли произведения И.Баха, успехи по математике были выше, чем в периоды, когда они больше внимания уделяли произведениям других композиторов. Но в эти периоды повышалась успеваемость по гуманитарным предметам. Игра на музыкальном инструменте развивает «мелкую моторику», которая тесно связана с нейронными зонами в головном мозге. Вот почему систематическая тренировка пальцев, игра одновременно обеими руками способствует развитию мелкой моторики и заодно развивает мышление, память, математические способности. Занятия музыкой помогают гармоничной работе обоих полушарий мозга, что повышает общий уровень интеллекта ребенка и академическую успеваемость в целом. Великий музыкант, пианист, педагог Г.Нейгауз утверждал, что *«*… математика и музыка находятся на крайних полюсах человеческого духа, что этими двумя антиподами ограничивается и определяется вся творческая духовная деятельность человека и, что между ними размещается все, что человечество создало в области науки и искусства».

Ранний музыкальный опыт, а также музыкальная деятельность (пение, движение под музыку, музицирование, слушание музыки и т.д.) открывают доступ к врожденным механизмам, ответственным за восприятие, понимание музыки и расширяет использование этих механизмов для образования других высших функций мозга. Научно доказано, что дети, одновременно посещающие две школы – общеобразовательнюую и либо музыкальную, либо художественную, эмоционально более развиты и менее подвержены стрессам.

Дети, которые чаще соприкасаются с классической музыкой, отличаются от своих сверстников: у них более развиты процессы восприятия, памяти; речевые, орфографические и вычислительные навыки; такие дети более дисциплинированны и эмоциональны. Мыслительные процессы у таких детей отличаются более высокой скоростью мышления и полифоничностью, т.е. способностью одновременно обрабатывать большое количество разнообразной информации.

Иссходя из выше изложенного можно смело утверждать, что занятия музыкой напрямую влияют на развитие логики, математических способностей, на концентрацию внимания, на память, формируют творческую личность.

Список литературы:

1. Бехтерев В.М. Вопросы, связанные с лечением и гигиеническим значением музыки //Обозрение психиатрии, неврологии и экспериментальной психологии. Петроград:Изд-во К.Л.Риккера, 1916, N4, с.
2. Бехтерев В.М.Значение музыки в эстетическом воспитании ребенка первых дней его детства. //Вестник воспитания. Изд-во Типо-литография И.Н.Кушнеревъ и К, 1915. N6 // 105-124//
3. Бонфельд М.Ш. Введение в музыкознание. – М.: Владос, 2001. – 224 с.
4. Веберн А. Лекции о музыке. Письма. – М.: Музыка, 1975. – 320 с.
5. Волошинов А.В. Еще раз о математической традиции красоты // Вопросы философии. – 2008. – № 8. – С. 102-112.
6. Гадамер Г. Актуальность прекрасного. – М.: Искусство, 1991. – 367 с.
7. Золтаи Д. Этос и аффект. – М.: Прогресс, 1977. – 371 с.
8. Кирнарская Д.К. Десять причин отдать ребенка в музыкальную школу // Музыкальная психология и психотерапия. – 2009. – № 6. – С. 75-78.

PHYSICAL SCIENCES

PHOTOMETRİC AND SPECTROSCOPİC VARİABİLİTY İN HERBİG STARS

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Abstract

The article explain the majority of Herbig stars are in binaries ($\gtrsim$ 70%). The mass ratios of the binary Herbig stars indicates that the binaries form from disk fragmentation. Given that many of these are unresolved at arcsecond resolution, this also has important implications for interpreting the X-ray properties of Herbig stars.

Herbig stars display photometric and spectroscopic changes on timescales ranging from hours to months and longer. The larger amplitude photometric changes can be traced back to variable dust obscuration from an orbiting disk, while variability at smaller, milli-magnitude, amplitudes can be analyzed with asteroseismology. Spectroscopically, variable line emission is mostly associated with the accretion process, while variable absorption lines can be due to changes in the accretion process itself, but can also be caused by infalling rocky material such as exo-comets.

Keywords: spectroscopic, photometric, intermediate-mass stars, variability.

Introduction

Over the last twenty-five years, interferometric observations at millimeter wavelengths of gas emission from disks surrounding young stars have allowed astronomers to determine the dynamical masses of these young stars [3, 14, 19, 21, 22]. The Atacama Large Millimeter Array (ALMA), with its high spatial resolution and sensitivity, has enabled the measurement of increasingly large samples of dynamical masses. These measurements serve as a critical benchmark for testing stellar evolution models and, consequently, the ages and masses derived from them. Braun et al. [3] assembled the most extensive such sample to date and reported that, for stars with model-inferred masses between 1.3 and 3.0 $M_{\odot}$, the evolution models predict masses that are systematically lower than the dynamically measured masses by approximately 5% to 14%.

It can be informative to examine Herbig stars within the context of their locations on the Hertzsprung-Russell (HR) diagram. Vioque et al. [24] plotted 218 known and candidate Herbig stars with precise Gaia DR2 parallaxes [5] on the HR diagram; a version of this plot is shown in Figure 1. For reference, several theoretical evolutionary tracks and isochrones are overlaid. As anticipated, most Herbig stars are located at or above the Zero-Age Main Sequence (ZAMS), indicating that intermediate-mass stars typically stop accreting material shortly before or soon after reaching the ZAMS. Herbig Be stars, which are more massive, are less numerous than Herbig Ae stars – a trend consistent with both the Initial Mass Function and the shorter evolutionary timescales associated with higher-mass stars as they approach the Main Sequence.

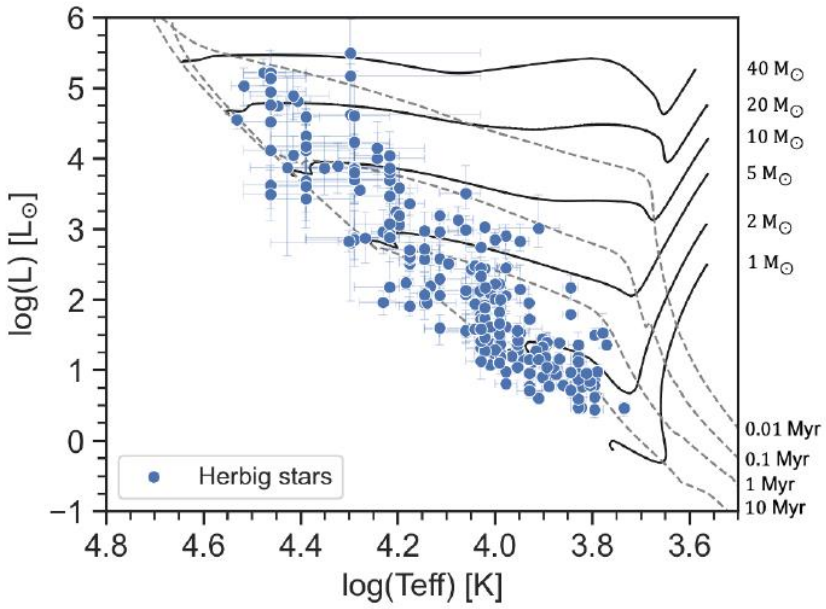

Fig. 1. *HR diagram containing 218 Herbig stars with high quality DR2 Gaia parallaxes (adapted from Vioque et al. (2018), their Figure 2).*

Higher-mass Herbig stars are consistently younger than their lower-mass counterparts (see Figure 2). The ages of the lower-mass Herbig stars generally span from a few million years up to around 10 million years. These older age estimates have important implications for the evolution and longevity of their circumstellar disks, a topic that will be addressed following a summary of the stellar properties.

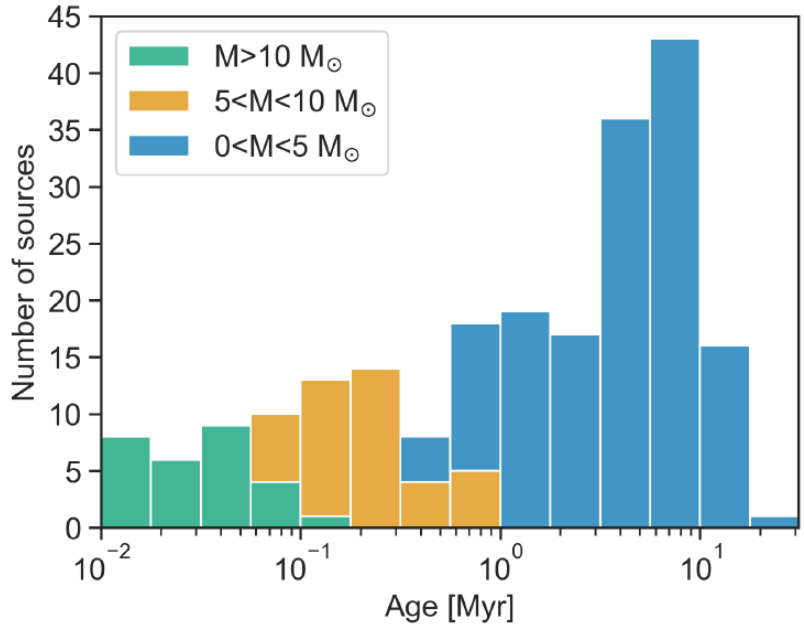

Fig. 2. *The age distribution of the 218 Herbig stars (Vioque et al. 2018). As shown in the diagram, the highest-mass stars have the smallest ages. Most Herbig Ae stars, and thus their disks, are older than several million years.*

Binaries among Herbig stars

Herbig stars are predominately found in binary systems, and many of these are found at arcsecond scales. Leinert et al. [16] and Pirzkal et al. [18], both investigations found a binary frequency of approximately 70% within this parameter range, with a suggestion that Herbig Be stars have a higher tendency to exist in binary systems. Wheelwright et al. [25] managed to spectroscopically resolve some previously undetected binaries and concluded that their mass ratios are near unity. This finding is inconsistent with random pairing from the Initial Mass Function (IMF), which would be expected if stellar capture were the dominant binary formation pathway. The same research group later reported in Wheelwright et al. [25] that the alignment between the binary components and the disks around the primary stars supported disk fragmentation as the likely formation mechanism.

Similar arguments in favor of fragmentation as the origin of Herbig binaries were advanced by Arun et al. [1], who announced the discovery of a widely separated

(6.6″) Herbig Ae–M star binary. Given the large separation, fragmentation at an earlier evolutionary stage was considered the most plausible scenario.

Surveys conducted with the Very Large Telescope Interferometer (VLTI) by Lazareff et al. [15, observing in the H-band with 51 targets] explored smaller orbital separations with contrast sensitivities comparable to earlier studies. These surveys resulted in few companion detections. However, it should be noted that the target selection was biased against known radial-velocity binaries, as the observations were primarily designed to study circumstellar disks. Despite this, milli-arcsecond Herbig Be binaries, corresponding to physical separations below 500 AU, have been detected using VLTI data [12, 13].

Finally, the smallest separation regimes can be investigated spectroscopically, either by detecting radial velocity variations or by directly observing double-lined spectroscopic binaries. There has been limited work in this area, with the spectroscopic survey of 42 Herbig stars by Corporon & Lagrange [6] remaining the largest dedicated study to date. This latter category includes spatially resolved objects with known separations around 0.5″; consequently, the observed close binary fraction based solely on radial velocity variations stands at 17%.

Photometric variability

Herbig stars exhibit distinct photometric variability across different wavelengths, providing key insights into their circumstellar environments. Studies have documented large, non-periodic optical brightness variations reaching up to $\Delta V \sim 3$ mag [10]. A defining phenomenon, known as UXor variability, was characterized through detailed observations of the star UX Ori. This behavior involves an initial reddening as the star fades, followed by a reversal to a bluer color during deep minima – the "blueing effect" [2, 11]. Concurrent increases in polarization indicate scattering by circumstellar dust. Multi-technique observations [8, 9] support a model where this effect is caused by opaque dust clouds in the inner disk transiting the line of sight.

In contrast, near-infrared (NIR) variability is significantly more subdued. Quasi-simultaneous optical and NIR monitoring of Herbig Ae stars by Eiroa et al. [7] revealed optical variations up to 0.5 mag, compared to typical NIR variations of only ~0.1 mag. For most objects in their sample, the optical and NIR variations were correlated, linking the origin of NIR variability to thermal re-emission from hot dust in the inner disk. The star UX Ori itself was an exception, showing no such correlation, which was attributed to rotational modulation from starspots. Subsequent analysis by Vioque et al. [24] estimated that roughly 25% of Herbig stars exhibit UXor-like variations, with Herbig Be stars being notably less variable.

Furthermore, high-precision space-based photometry has enabled the detection of low-amplitude, milli-magnitude pulsations in some Herbig Ae stars [4, 26, 27, see compilation by [23]]. These pulsations are identified as δ Scuti-type variability [20], originating from radial oscillations in stars located within the classical instability strip. This milli-magnitude variability opens the door to asteroseismology of pre-main-sequence stars. A prominent example is HD 139614, for which asteroseismic modeling yielded an age of about 11 Myr [17]. This relatively old age confirms that gas-rich circumstellar disks can persist for substantial periods.

Spectroscopic variability

Herbig stars exhibit variability not only in their brightness but also in their spectral emission lines. Studies indicate that variations in the strength and shape of these emission lines are linked to the rotation of the star, which periodically brings the regions of mass accretion in and out of view. This type of variability is generally less pronounced in Herbig stars than in younger T Tauri stars, where the accretion process is more strongly influenced by magnetic fields.

Research focusing on larger samples, particularly monitoring the Hα emission line, shows that variability occurs across a wide range of timescales. The amplitude of change grows from very short timescales (minutes) to longer ones (days to weeks), and can be observed even over several years. This pattern suggests the changes originate in a compact region close to the star and are primarily driven by fluctuations in the rate at which material accretes onto the stellar surface. Therefore, emission line variability serves as a key indicator of ongoing accretion in these systems.

Another distinct form of spectroscopic variability involves transient absorption features from metals. In this phenomenon, absorption lines can appear suddenly and become progressively more red-shifted over just a few hours. This signature is interpreted as evidence for gas released from evaporating, comet-like bodies falling onto the star. Observations show that a significant proportion of Herbig stars display this behavior, linking it to the presence of solid bodies within their disks. This spectral signature is considered an indirect method for detecting the building blocks, or possibly even planets, within these circumstellar environments.

Conclusion

This study underscores the complex and dynamic nature of Herbig stars. Photometric and spectroscopic observations point to both dust clouds in the circumstellar disk and instabilities in the accretion process as primary drivers of their variability. Furthermore, the high frequency of binary systems among these stars and their near-unity mass ratios highlight the dominant role of disk fragmentation in their formation. Finally, the observed relatively long (several million years) active disk phase in these stars confirms the presence of a prolonged and dynamic environment for planet formation around intermediate-mass stars. Future high-resolution and long-term monitoring studies will provide deeper insight into the processes of accretion, obscuration, and material dynamics occurring in these young stellar systems.

References:

1. Arun, A., Haque, M. M., Washington, S., et al. (2021). A systematic review of traffic conflict-based safety measures with a focus on application context. Analytic methods in accident research, 32, 100185.

2. Bibo, E. A., The, P. S. (1990). A study of the Herbig Ae-type star UX Orionis: its remarkable behavior in the colour-magnitude diagram, and the properties of its dust shell. A&A, 236, p.155.

3. Braun, V., Clarke, V., Boulton, E., et al. (2021). The online survey as a qualitative research tool. International journal of social research methodology, 24(6), p.641-654.

4. Casey, M. P., Zwintz, K., Guenther, D. B., et al. (2013). MOST observations of the Herbig Ae δ-Scuti star HD 34282. Monthly Notices of the Royal Astronomical Society, 428(3), p.2596-2604.

5. Collaboration, G., Mignard, F., Klioner, S. A., et al. (2018). Gaia Data Release 2. A&A, 616, p.14.

6. Corporon, P., Lagrange, A. M. (1999). A search for spectroscopic binaries among Herbig Ae/Be stars. Astron. Astrophys. Suppl. Ser., 136, p.429-444.

7. Eiroa, C., Oudmaijer, R. D., Davies, J. K., et al. (2002). On the simultaneous optical and near-infrared variability of pre-main sequence stars. A&A, 384, p.1038-1049.

8. Grinin, V. P., The, P. S., de Winter, D., et al. (1994). The β Pictoris phenomenon among young stars. I. The case of the Herbig AE star UX Orionis. A&A, 292, p.165-174.

9. Grinin, V. P. (1992). Young stars with non-periodic Algol-type minima. Astronomical and Astrophysical Transactions, 3, p.17-32.

10. Herbst, W., Herbst, D., Grossman, E. J., et al. (1994). Catalogue of UBVRI photometry of T Tauri stars and analysis of the causes of their variability. Astrophys. J., 108, 1906-1923.

11. Huseynova, F. S., Ismayilov, N. Z., Alishov. S. A. (2025). Photometric and Spectral Study of the Star AS 442. Young Researcher Scientific & practical journal, Cild XI, №3, p. 90-100.

12. Koumpia, E., de Wit, W. J., Oudmaijer, R. D., et al. (2021). The first interferometric survey of massive YSOs in the K-band-hot dust, ionised gas, and binarity at au scales. Astronomy & Astrophysics, 654, p.109.

13. Kraus, M., Liimets, T., Cappa, C. E., et al. (2017). Resolving the circumstellar environment of the Galactic B [e] supergiant star MWC 137 from large to small scales. The Astronomical Journal, 154(5), p.186.

14. Law, A. M. (2022). How to build valid and credible simulation models. In 2022 Winter, Simulation Conference (WSC) p.1283-1295

15. Lazareff, B., Berger, J. P., Kluska, J., et al. (2017). Structure of herbig aebe disks at the milliarcsecond scale-a statistical survey in the h band using pionier-vlti. Astronomy & Astrophysics, 599, p.85.

16. Leinert, C., Bowyer, S., Haikala, L. K., et al. (1998). The 1997 reference of diffuse night sky brightness. Astronomy and Astrophysics Supplement Series, 127(1), p.1-99.

17. Murphy, S. J., Joyce, M., Bedding, T. R.,(2021). A precise asteroseismic age and metallicity for HD 139614: a pre-main-sequence star with a protoplanetary disc in Upper Centaurus–Lupus. Monthly Notices of the Royal Astronomical Society, 502(2), p.1633-1646.

18. Pirzkal, N., Spillar, E. J., Dyck, H. M. (1997). A Search for close bright companions to AeBe Stars. ApJ, 481, p.392-395.

19. Rabeony, H., Petit-Paris, I., Garnier, J., et al. (2014). Inhibition of keratinocyte differentiation by the synergistic effect of IL-17A, IL-22, IL-1α, TNFα and oncostatin M. PloS one, 9(7), e101937.

20. Ripepi, V., Cioni, M. R. L., Moretti, M. I., et al. (2017). The VMC survey–XXV. The 3D structure of the Small Magellanic Cloud from Classical Cepheids. Monthly Notices of the Royal Astronomical Society, 472(1), p.808-827.

21. Simon, M., Houghton, S. M., Aquino, K. (2000). Cognitive biases, risk perception, and venture formation: How individuals decide to start companies. Journal of business venturing, 15(2), p.113-134.

22. Simon, T., Hero, B., Schulte, J. H., et al. (2017). 2017 GPOH guidelines for diagnosis and treatment of patients with neuroblastic tumors. Klinische Pädiatrie, 229(03), p.147-167.

23. Steindl, T., Zwintz, K., Barnes, T. G., et al. (2021). Pulsational instability of pre-main-sequence models from accreting protostars-I. Constraining the input physics for accretion with spectroscopic parameters and stellar pulsations. Astronomy & Astrophysics, 654, p.32.

24. Vioque, M., Oudmaijer, R. D., Baines, D., et al. (2018). Gaia DR2 study of Herbig Ae/Be stars. A&A, 620, p.17.

25. Wheelwright, S. J., Sadek, S. A., Baron-Cohen, S., et al. (2011). A behavioral comparison of male and female adults with high functioning autism spectrum conditions. PloS one, 6(6), e20835.

26. Zwintz, K., Fossati, L., Ryabchikova, T., et al. (2014). Echography of young stars reveals their evolution. Science, 345(6196), p.550-553.

27. Zwintz, K., Kallinger, T., Guenther, D. B., et al. (2009). MOST photometry of the enigmatic PMS pulsator HD 142666. Astronomy & Astrophysics, 494(3), p.1031-1040.

ENTROPY OF NONREGULAR CONDENSED SYSTEMS WITH POLYATOMIC IMPURITIES

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Abstract
Nonregular condensed systems with polyatomic impurity particles are considered in this paper. The calculation of the thermodynamic characteristics of the system, including the change in entropy of nonregular condensed systems upon the introduction of polarizable, charged polyatomic impurity particles is carried out. The change in the system's free energy and its dependence on temperature is calculated in order to determine the change in entropy of the system. A Green's function apparatus is used to perform the calculations.

Keywords: entropy, free energy, condensed systems, green functions, polyatomic impurities, Hamiltonian

Nonregular condensed systems with polyatomic impurity particles are considered [1 – 10]. This paper calculates the thermodynamic characteristics of the system, including the change in entropy of nonregular condensed systems [4 –7] upon the introduction of polarizable, charged polyatomic impurity particles. Naturally, to calculate the change in entropy of the system, it is necessary to calculate the change in the system's free energy and its dependence on temperature.

To calculate the thermodynamic characteristics of condensed systems with impurity particles, the apparatus of temperature Green functions for nonregular condensed systems is convenient, allowing one to take into account the effects of frequency and spatial dispersion of the system and the specifics of the interaction of impurity particles with the medium.

The total change in the free energy of nonregular condensed system upon the introduction of impurity particles includes the following components:

1. Work associated with the formation of the cavity containing the impurity particle.

2. Free energy associated with the translational and rotational motion of the particle as a whole.

3. Electrostatic energy associated with the interaction of the impurity particle with the medium.

As a rule, the last term contributes the largest change in the free energy of a system upon the introduction of an impurity into a condensed system. It is this change in the system's free energy that provides the main contribution to the change in the system's entropy, which is calculated in this work.

It must be taken into account that the temperature dependence of the free energy of the system is not only explicit but also implicit. In particular, the characteristic correlation lengths of polarization fluctuations in the medium of complex condensed systems depend on temperature. For a system model that takes into account the interaction of polarization fluctuations in the medium with the static field of an impurity particle, this dependence can be present through the temperature dependence of the system's permittivity.

1. Hamiltonian of nonregular condensed system with polyatomic impurity particle

The Hamiltonian of a system in which a charged impurity particle is located in a condensed medium can be represented as:

$$H = H^m + \mathcal{H}^p - \frac{1}{2}\int d\vec{r}\langle\vec{P}(\vec{r})\rangle\vec{E}(\vec{r},Q) - \int d\vec{r}\delta\vec{P}(\vec{r})\vec{E}(\vec{r},Q) \quad (1)$$

Here H^m - is the Hamiltonian of polarized medium, $\mathcal{H}^p$ is the Hamiltonian of the impurity particle, $\langle\vec{P}(\vec{r})\rangle$ - is the average polarization of the medium, $\delta\vec{P}(\vec{r})$ - is fluctuation of polarization of the medium, $\vec{E}(\vec{r},Q)$ - is the electric field strength of the impurity, Q are the coordinates of the intramolecular vibrations of a particle.

According to the fluctuation-dissipation theory, the Fourier component over time of the average polarization of the system can be represented through the Green function as follows:

$$\langle\vec{P}(\vec{r},\omega)\rangle = -\int d\overrightarrow{r'}G_{P_\alpha P_\beta}\left(\overrightarrow{r},\overrightarrow{r'};\omega\right)E_\beta\left(\overrightarrow{r'};\omega\right) \quad (2)$$

where $G_{P_\alpha P_\beta}\left(\overrightarrow{r},\overrightarrow{r'};\omega\right)$ is the Fourier component over time of the Green function of the medium polarization operators.

After simple transformations, the Hamiltonian of the system can be represented as

$$H = \delta\Omega_0 + H^p + H^m + H^1_{int} + H^2_{int} \quad (3)$$

Here H^p - is the Hamiltonian of polarized particle, H^m is the Hamiltonian of polarized medium, H^1_{int} is the Hamiltonian of the interaction of polarization fluctuations of the medium with the static field of an impurity particle:

$$H^1_{int} = -\int d\vec{r}\delta\vec{P}(\vec{r})\overrightarrow{E_0}(\vec{r})\,;\ \overrightarrow{E_0}(\vec{r}) = \vec{E}(\overrightarrow{r},Q=Q_0) \quad (4)$$

In the formula (3) H^2_{int} is the Hamiltonian of the interaction of polarization fluctuations of the medium with intramolecular vibrations of the impurity

$$H^2_{int} = -\sum_n\int d\vec{r}\vec{v}_n(\vec{r})\,\delta\vec{P}(\vec{r})\delta Q_n \quad (5)$$

In formula (3) $\delta\Omega_0$ is the free energy of solvation of the particle, equal to

$$\delta\Omega_0 = \frac{1}{2}\int E_\alpha(\overrightarrow{r},Q=Q_0)\,G_{P_\alpha P_\beta}\left(\overrightarrow{r},\overrightarrow{r'};\omega=0\right)E_\beta\left(\overrightarrow{r'},Q=Q_0\right)d\vec{r}d\vec{r'} \quad (6)$$

The Hamiltonian H^m differs from the Hamiltonian of an unpolarized medium by the value

$$\delta F^m = \frac{1}{2}\int d\vec{r}\langle\vec{P}(\vec{r})\rangle\vec{E}(\vec{r},Q) \quad (7)$$

Within the framework of the linear response theory [4-5], the average polarization of the medium can be expressed through the strength of the electric field created by a polarized impurity particle, as a result for δF^m we have

$$\delta F^m = \frac{1}{2}\int E_\alpha(\vec{r},Q)\, G_{P_\alpha P_\beta}\left(\vec{r},\vec{r'};\omega = 0\right)E_\beta\left(\vec{r'},Q\right)d\vec{r}d\vec{r} \quad (8)$$

2. Free energy of nonregular condensed system with polyatomic impurity particle

The free energies of a condensed system with a polyatomic impurity particle $\delta\Omega_0$ and δF^m differ by the difference in the free energies of the impurity in the solvated state and in vacuum.

$$\delta\Omega_0 - \delta F^m = kTln\prod_{n=1}^{N} 2sh(\beta\omega_n/2) - kTln\prod_{n=1}^{N} 2sh(\beta\omega_{n0}/2) + J_0 \quad (9)$$

Where ω_n and ω_{n0} are frequencies of the n-th intramolecular vibration of the particle in a solvated state and in vacuum, J_0 is the difference between the minimal energies of a particle in a solvated state and in a vacuum.

As a result, the electrostatic part of the change in the free energy of the system, associated with the introduction of a polyatomic polarizable impurity particle into the condensed medium, is written in the form

$$\delta\Omega = \delta\Omega_0 + \delta F^m + \delta\Omega_1 + \delta\Omega_2 \quad (10)$$

where $\delta\Omega_1$ and $\delta\Omega_2$ are the changes in the free energy of the system associated with the interactions H_{int}^1 and H_{int}^2, and $\delta\Omega_0$ is free energy of solvation of a particle.

The retarded Green function of the polarization operators of the system in the case of the Debye approximation can be represented as

$$G^R\left(\vec{r},\vec{r'};\omega\right) = (C_0/4\pi)[\gamma_0/(\gamma_0 + i\omega)] \quad (11)$$

Where, γ_0 is a characteristic parameter of the system, and C_0 is a dimensionless constant equal to the difference between the reciprocals of the permittivities to the right and left (on the energy scale) of the corresponding absorption peak of the system.

3. Entropy of the system

If we do not take into account the temperature dependence of the correlation lengths of the polarization fluctuations of the medium on the temperature, then the change in the entropy of the system associated with the interaction of the polarization fluctuations of the medium with the static field of the impurity can be represented in the form

$$\delta S_1 = (\delta\Omega_1/C_0)(\partial C_0/\partial T) \quad (12)$$

where T is the temperature of the system.

The change in the entropy of a system caused by the interaction of polarization fluctuations of the medium with intramolecular vibrations of the impurity particle H_{int}^2, as well as the polarizability of the medium and impurity $\delta\Omega_0 + \delta F^m$ can be calculated for specific models of the Green functions of the medium's polarization fluctuation operators.

For the pole approximation of the Green function $G_{P_\alpha P_\beta}$, we obtain for the change in the entropy of the system:

$$\begin{aligned}\delta S_2 = {} & (k/2)ln[1-(U(0)/\omega_s)] - (kT/2)\left[1/\left(\omega_s - U(0)\right)\right]\sum_{i=1}^{m}(\partial/\partial T)\,(U_i/\omega_i) \\ & + kln\prod_{j=1}^{m+2}\Gamma\left[1-\left(\bar{\omega}_j/2\pi kT\right)\right] - kln\prod_{j=1}^{m}\Gamma[1-(\omega_i/2\pi kT)] \\ & - (1/2\pi)\sum_{j=1}^{m+2}\left\{\left[\left(\partial\bar{\omega}_j/\partial T\right) - \left(\bar{\omega}_j/T\right)\right]\psi\left[1-\left(\bar{\omega}_j/2\pi kT\right)\right]\right\} \\ & + (1/2\pi)\sum_{i=1}^{m}\{[(\partial\omega_i/\partial T) - (\omega_i/T)]\psi[1-(\omega_i/2\pi kT)]\} + k[ln(kT/\omega_s) - 1] \\ & + kln[2sh(\omega_s/2kT)] - (\omega_s/2T)\,cth(\omega_s/2kT) + (\partial J_0/\partial)\end{aligned} \quad (13)$$

Here, $\left[1-\left(\bar{\omega}_j/2\pi kT\right)\right]$ denotes the Γ -function, and $\left[1-\left(\bar{\omega}_j/2\pi kT\right)\right]$denotes the ψ function.

In formula 10.70, U(0) is the renormalized interaction of intramolecular vibrations of the impurity through the medium at zero frequency. For the pole approximation of the polarization fluctuation operators of the medium, the renormalized interaction is defined as

$$U(\omega_n) = \sum_{i=1}^{m}[u_i/(\omega_i - |\omega_n|)] \quad (14)$$

Here u_i and ω_i are experimental constants, m is the number of poles of the Green function of the operator of intramolecular vibrations of the impurity.

In formula 10.70, ω_s is the frequency of the intramolecular vibration of the impurity particle.

In formula 10.70, the derivatives $\partial\bar{\omega}_j/\partial T$cannot always be determined analytically. In this case $\partial\bar{\omega}_j/\partial T$ can be determined numerically, just like the frequencies.

For the Debye approximation of the frequency dependence of the Green function of the polarization operators of the medium for changes in the entropy of the system, we obtain

$$\delta S_2 = (\omega_s/2kT)ln(1-\acute{æ}) - (kT/2\,\omega_s)[1/(1-\acute{æ})][\partial U(0)/\partial T] + kln\prod_{j=1}^{3}\Gamma\left[1-\left(\overline{\omega}_j/2\pi kT\right)\right] - klnГ\left[1-(\gamma_0/2\pi kT)+kln[(kT/\omega_s)-1]\right] + kln2sh(\omega_s/2kT) - (\omega_s/2T)cth(\omega_s/2kT) - (1/2\pi)\sum_{j=1}^{3}\left[\left(\partial\overline{\omega_j}/\partial T\right)-\left(\overline{\omega_j}/T\right)\right]\psi\left[1-\left(\overline{\omega_j}/2\pi kT\right)\right] + [(\partial\gamma_0/\partial T)-(\gamma_0/T)]\psi[1-(\gamma_0/2\pi kT)] \quad (15)$$

Here, the coefficient of the coupling strength of intramolecular vibrations with the medium is equal to

$$\acute{æ} = -AC_0/4\pi \quad (16)$$

Here, the coefficient A for a spherically symmetric particle placed in a local homogeneous medium is equal to

$$A_{ss'} = -(8\pi/3r_0^3)C_0(\partial d/\partial Q)^2 = -(8\pi C_0/3r_0^3)\omega_0(\partial d/\partial q)^2 \quad (17)$$

where r_0 is the particle radius, ω_0 is the frequency of the intramolecular vibration, $\partial d/\partial q$ is the derivative dipole moment along the coordinate of the intramolecular vibration.

In an approximation in which the frequency dependence of attenuation on temperature can be neglected, for weak coupling with the medium, we have

$$\partial\overline{\omega_{2,3}}/\partial T = [\gamma_0\omega_s^2/2(\omega_s^2+\gamma_0^2)][\partial\acute{æ}(T)/\partial T] \mp i\omega_s[\gamma_0^2/2(\omega_s^2+\gamma_0^2)][\partial\acute{æ}(T)/\partial T] \quad (18)$$

For an impurity particle placed in a local homogeneous isotropic medium, the parameter has the form

$$[\partial\acute{æ}(T)/\partial T] = -A/2\pi\omega_s[(1/\varepsilon_r^2)(\partial\varepsilon_r/\partial T) - (1/\varepsilon_{st}^2)(\partial\varepsilon_{st}/\partial T)] \quad (19)$$

where ε_r and ε_{st} are the IR and static values of the permittivity of the medium.

Conclusion

Nonregular condensed systems with polyatomic impurity particles are considered. The thermodynamic characteristics of the system are calculated, including the change in entropy of nonregular condensed systems upon the introduction of polarizable charged polyatomic impurity particles into the system. To calculate the change in entropy of the system, the change in free energy of the system and its dependence on temperature are calculated.

To calculate the thermodynamic characteristics of condensed systems with impurity particles, we used the apparatus of temperature Green functions for nonregular condensed systems. The calculations took into account the effects of frequency and spatial dispersion of the system and the specific interactions of the impurity particles with the medium.

The paper notes that the main contribution to the change in the free energy of a system upon the introduction of an impurity into a condensed system is the electrostatic component associated with the interaction of the impurity particle with the environment. It is this change in the free energy of the system that provides the main contribution to the change in the entropy of the system, which is calculated in this paper.

References:

1. T.A. Marsagishvili, M.N. Machavariani, N.Sh. Ananiashvili, N.V. Giorgadze. Thermodynamic characteristics of non-regular condensed systems with impurity polyatomic particles. Norwegian Journal of development of the International Science, №138, 2024, n. 7, p. 7 – 10. ISSN 3453-9875, https://doi.org/10.5281/zenodo.13325895.
2. Marsagishvili, M. Machavariani. Theoretical models of charge transfer processes in nonpolar media. Chemical Problems. 2024, v. 22 (3), p.324-330. ISSN 2221-8688. DOI: 10.32737/2221-8688-2024-3-324-331.
3. Tamaz Marsagishvili, Marine Matchavariani. Proton transfer processes in complex condensed systems. Norwegian Journal of development of the International Science, №162, 2025, p. 58 – 61. ISSN 3453-9875, https://doi.org/10.5281/zenodo.16875607.
4. Kleidon, A.; et., al. Non-equilibrium Thermodynamics and the Production of Entropy. Heidelberg: Springer. 2005, 254 p.
5. *Lavenda, Bernard H. A new perspective on thermodynamics (Online-Ausg. ed.). 2010, 226 p., New York: Springer.* ISBN 978-1-4419-1430-9.
6. Atkins, Peter; Julio De Paula. Physical Chemistry, 2006, 8th ed. Oxford University Press. p. 79. ISBN 978-0-19-870072-2.
7. Sethna, James P. Statistical mechanics: entropy, order parameters, and complexity ([Online-Ausg.] ed.). Oxford: Oxford University Press. 2006, p. 78. ISBN 978-0-19-856677-9.
8. Jaynes, E. T. The Gibbs Paradox. In Smith, C. R.; Erickson, G. J.; Neudorfer, P. O. (eds.). Maximum Entropy and Bayesian Methods (PDF). 1992, Dordrecht, Holland: Kluwer Academic. pp. 1–22. Retrieved 17 August 2012.
9. Kannan Jagannathan. Anxiety and the Equation: Understanding Boltzmann's Entropy. American Journal of Physics. 2019, v. 87 (9), p. 765. doi:10.1119/1.5116583.
10. E.Zanchini, G.P.Beretta. Recent Progress in the Definition of Thermodynamic Entropy. Entropy, 2014, v.16, N 3, p. 1547-1570. doi:10.3390/e16031547.

POLITICAL SCIENCES

STRATEGIC VISION FOR RETURN TO WESTERN AZERBAIJAN

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Abstract

The issue of return to Western Azerbaijan holds significant strategic importance for restoring historical justice and national sovereignty of the Azerbaijani people. This article examines the historical context of Western Azerbaijan, including deportations during the Soviet era and the consequences of Armenia's mono-ethnic policies. Legal aspects are analyzed through the lens of international law concerning the right of return and Armenia's international obligations. The strategic approach encompasses diplomatic lobbying, public diplomacy, infrastructure planning, and non-violent methods. Additionally, the article discusses socio-cultural and diaspora activities, international cooperation, challenges, prospects, and information security issues. Finally, essential conditions for return and a proposed strategic roadmap aimed at contributing to long-term peace are presented. The study emphasizes the necessity of a multifaceted approach for resolving the Western Azerbaijan issue within regional stability and international law frameworks.

Keywords. Western Azerbaijan, right of return, deportation, diplomatic lobbying, public diplomacy, diaspora, infrastructure planning, regional stability, human rights, historical memory, information security

Introduction.

Relevance of the topic. The issue of the return of our compatriots deported from Western Azerbaijan occupies an important place in the modern foreign and domestic policy of Azerbaijan. This issue is of strategic importance not only in terms of restoring historical justice, but also in terms of international law, regional security and national solidarity. Against the background of the normalization process with Armenia, bringing the issue of Western Azerbaijan to the agenda on the legal and political level, as well as ensuring a planned and phased return, strengthens Azerbaijan's statehood position. The meeting of President Ilham Aliyev with the "Western Azerbaijan Community" in 2022 and the presentation of the "Return Concept" indicate that this issue is prioritized at the level of official state policy.

Purpose and methodology of the article. The purpose of this article is to comprehensively analyze the legal basis, diplomatic opportunities and regional geopolitical framework of the issue of return to Western Azerbaijan from a strategic perspective. At the same time, the stages of the return process, the challenges ahead and possible solutions are examined. The article is written using a scientific-theoretical approach, as well as analysis and forecasting methods. The data is systematized mainly on the basis of academic literature, state documents, international legal norms, and official sources of the West Azerbaijan Community.

Historical roots of the concept of Western Azerbaijan. The concept of Western Azerbaijan was formed not only as a geographical, but also as an ethno-historical and political term. This concept covers the regions of Goycha, Zangezur, Daralayaz, Aghbaba, Basarkechar, Amasiya, Vedibasar, Garagoyunlu, Gafan and other regions in the current territory of the Republic of Armenia, where Azerbaijani Turks have lived since ancient times. In the 18th–19th centuries, several Azerbaijani khanates and districts existed in these territories, and the vast majority of the population living here were Azerbaijani Turks. After the Turkmenchay Treaty of 1828, a massive resettlement of Armenians to the region began, which led to serious changes in the ethnic composition of the population. As a result of this purposeful policy implemented by the Russian Empire, the demographic and ethnic structure of Western Azerbaijan was artificially changed. By the beginning of the 20th century, **The relevance and legal and political context of the idea of return.** The issue of the return of West Azerbaijani Turks is one of the important directions of the peace policy of the Republic of Azerbaijan based on international law and human rights. Although the idea of return may seem like a humanitarian issue at first glance, in fact, it is rooted in fundamental legal principles, especially international humanitarian law, property rights, minority rights, and the right of return of populations subjected to ethnic cleansing. According to Article 13 of the UN Universal Declaration of Human Rights, "everyone has the right to return to their country". At the same time, since "ethnic cleansing" is considered a crime under international law, the elimination of the consequences of this crime is also accepted as an international obligation. In this sense, the right of return of West Azerbaijani Turks has not only moral, but also legal legitimacy. The Azerbaijani state is trying to resolve this issue without resorting to force, but through diplomatic and political means. President Ilham Aliyev's support for the activities of the West Azerbaijan Community in 2022, the preparation of the "Return Concept" and the appeals addressed to the international community demonstrate the existence of political will in this direction. The relevance of the idea of return is also directly related to the formation of a peace

and security environment in the region in the post-conflict phase. Against the background of the normalization of relations with Armenia and agreements that will be accompanied by mutual legal guarantees, the West Azerbaijan issue has become an integral part of the regional geopolitical agenda. Armenians had already gained numerical superiority in the region, and armed attacks, massacres and deportations were carried out against Azerbaijani Turks in stages. For this reason, the concept of "Western Azerbaijan" is valued not only as a lost territory in Azerbaijani history, but also as a national-political symbol preserved in the memory of an ethnos whose population was forcibly removed and whose rights were violated. This term is a concept that expresses both ethnic identity and the claim of national rights. Historical presence of Azerbaijani Turks in Western Azerbaijan. The territory of Western Azerbaijan, that is, the present-day Republic of Armenia, has been a region where Azerbaijani Turks have lived and created culture for centuries. According to historical sources and official documents, Azerbaijani Turks have dominated both rural and urban areas in regions such as the Goycha Lake area, Zangezur, Vedibasar, Daralayaz, Aghbaba, and Amasya. Ancient Turkic-language toponyms, mosques, cemeteries, and written monuments clearly reveal the traces of the Azerbaijani people in this geography. After the Turkmenchay Treaty concluded in 1828, the Russian Empire began to resettle Armenians from Iranian and Ottoman territories to the region. This resettlement policy was not only aimed at changing demographic proportions, but also aimed at forming the foundations of the Armenian statehood to be created in the future. Until the beginning of the 20th century, Azeri Turks constituted the majority of the population in the region.

Deportations during and after the Soviet era. The mass deportation of Azerbaijani Turks from Western Azerbaijan was carried out in four main stages: 1905–1906: As a result of the first organized attacks by Armenian armed groups in the Caucasus, hundreds of Turkish villages were destroyed. 1918–1920: During the Dashnaktsutyun government, a policy of genocide and ethnic cleansing was carried out against Azerbaijani Turks. 1948–1953: By decision of the USSR Council of Ministers, more than 100 thousand Azerbaijani Turks were deported from the Armenian SSR to the Kur-Araz lowland of the Azerbaijan SSR. This migration was forced and families were forced to leave their homelands. 1987–1991: With the collapse of the USSR and Armenia's independence, another wave of attacks against Azerbaijani Turks began. Taking advantage of the vacuum created by Gorbachev's "perestroika" policy, Armenian radical groups organized systematic attacks against Azerbaijani Turks. During this period, more than 250 thousand Azerbaijani Turks were expelled from Western Azerbaijan, and Armenia became a de facto mono-ethnic state. **Formation of a mono-ethnic policy in Armenia.** After the Republic of Armenia gained independence, a purposeful policy was pursued in the country towards the establishment of a mono-ethnic state. No mechanism was created in the Constitution and other legal documents to reflect ethnic diversity. The Armenian government, especially since the 1990s, has taken a negative position on the issue of the return of Azerbaijani Turks. Their property rights were not recognized, international obligations on the right of return were not observed, and the historical and cultural heritage was either destroyed or falsified. All this indicates that the policy of intolerance towards national minorities in Armenia has deep roots. As a result, today Armenia is recognized as the only mono-ethnic state in the region, and this fact is also noted by international human rights organizations.

The right of return in international law. The right of West Azerbaijani Turks to return to their homeland is based on fundamental principles of international law. This right is clearly enshrined in several international instruments:

Article 13 of the UN Universal Declaration of Human Rights: “Everyone has the right to freedom of movement and residence within their country” and “Everyone has the right to return to his country” [24].

Article 12 of the International Covenant on Civil and Political Rights: “No one shall be deprived of the right to return to his country” [25].

The European Convention on Human Rights and the case law of the European Court of Human Rights protect the right of individuals to return to their homes and property. According to these instruments, the right of return of persons displaced from their homeland as a result of deportation is unequivocally recognized and this right may not be violated on ethnic, religious or political grounds.

International obligations of Armenia. The Republic of Armenia is also a state that has ratified international legal instruments and is obliged to act in accordance with the requirements of these documents. Armenia has acceded to the following international documents:

The main human rights instruments of the UN (Declaration and Covenants),

As a member of the Council of Europe, the European Convention on Human Rights (ECHR),

The 1951 Convention Relating to the Status of Refugees and its 1967 Protocol. According to these documents, Armenia must: Recognize the right of return of deported persons, Ensure their property and ownership rights, and Bear international responsibility for the crime of ethnic cleansing. Obstruction of return, discrimination, and destruction of historical and cultural heritage constitute violations of international humanitarian law and human rights principles [9].

The basis of the legal claims of the Azerbaijani government. The Republic of Azerbaijan defends the right of return of our compatriots deported from Western Azerbaijan based on international law. The following legal grounds are cited in this regard: Recognition of the forced deportation of our compatriots as an act of ethnic cleansing prohibited by international law. Documentation of the facts of violation of the property rights of Azerbaijani citizens and the demand for the restoration of these rights. Evaluation of the right of return not only as a humanitarian issue, but also as the restoration of violated norms and principles of international law [26]. The legal framework presented by Azerbaijan is prepared in accordance with international law. The “Return Concept” also systematizes these legal grounds and presents them openly to the world community.

Lobbying activities at the diplomatic and international level. In order to keep the issue of return to Western Azerbaijan on the international agenda and to promote it as a legitimate legal claim, targeted lobbying activities are necessary, along with diplomatic efforts. The Azerbaijani government should cooperate with various international organizations in this direction and regularly raise the issue on platforms such as the UN, OSCE, EU and the Council of Europe. At the same time, it is important for Azerbaijani diplomats, lawyers and representatives of the diaspora to specialize in this area. The main goals within the framework of this activity are: Documenting the facts of deportation and presenting them to international organizations, Substantiating the right of return in accordance with international legal norms, and bringing to the agenda the obligations that Armenia has undertaken but not fulfilled in this regard.

Public diplomacy and information warfare. A strong public diplomacy strategy is needed to properly and effectively communicate the issue of Western Azerbaijan to international public opinion. The main goal here is to introduce the history, ethno-cultural heritage and facts of deportation of Western Azerbaijan to the international media, academic circles and NGOs. The following tools should be used in this direction: Documentaries, articles and reports in foreign languages should be prepared, the access of the Western Azerbaijan Community to the international press, especially in Western countries, should be increased, effective response strategies should be developed against Armenian propaganda on social media platforms. In the context of information warfare, evidence-based responses, fact-rich digital archives and analytical content should be prepared against Armenia's attempts to falsify history.

Infrastructure planning and phased implementation for return. There are not only political and legal, but also practical organizational stages of return. Here, the following issues should be taken into account first: Restoration and documentation of property and land registries; Clarification of property rights in historical areas is the initial step for return. Construction of a living infrastructure that ensures the voluntary return of internally displaced persons; Basic needs, including housing, water, electricity, education and health facilities, should be planned. Social adaptation and employment programs Vocational training and social security programs should be implemented to integrate the returning population into the new environment. This process should be implemented in a phased manner, first with pilot projects, and then in an expanded form. Conducting the process in a transparent, voluntary and safe manner can attract the support of the international community.

Non-violent and legal approach. The Azerbaijani state prefers international law, mutual negotiations and a peace model rather than the use of force and military means in the return process. This approach forms the basis of international legitimacy and demonstrates Azerbaijan's peace-loving position. The idea of return: It should be implemented without the use of force, by persuading the other party with international pressure on the political and legal level, by mutually agreeing on security guarantees, and by involving international mediators, especially the UN and OSCE mechanisms. This approach is also a necessary condition for ensuring long-term stability and peace with Armenia.

Putting the issue on the international agenda through diplomatic means. In order to put the issue of Western Azerbaijan on the international agenda, the existing diplomatic tools should be used first. The Azerbaijani state should strengthen the following directions in this direction: Bilateral and multilateral diplomacy: The issue should be consistently raised in the negotiations with Armenia, as well as on the agendas of organizations such as the OSCE, the UN, the Council of Europe and the Organization of Islamic Cooperation. It is of strategic importance for Azerbaijan to keep this issue on the agenda within the framework of the peace agreement with Armenia. International recognition of the West Azerbaijan Community: It is important to present this public entity as a legitimate actor and to submit legal and political documents to international organizations through it. Cultural diplomacy: Documenting historical facts, forced deportations, and the destruction of national and cultural heritage and communicating them to international academic and legal circles is an important means of gaining international sympathy [9]. This approach aims to draw the attention of the international community to the ethnic cleansing policy that Armenia has implemented in the past and for which it is still responsible.

Reintegration within the framework of peace and security mechanisms. The process of return to Western Azerbaijan should not be limited to legal and diplomatic steps alone, this process should take place within the framework of peace and security. The main issue here is ensuring the security of both Azerbaijani Turks and those currently living in the region. The reintegration model should be based on the following mechanisms: A reintegration plan to be implemented with the participation of international observers can guarantee the prevention of violence during the return of the population. Confidence-building measures: Reducing tensions in mutual relations through historical dialogues, cultural exchange programs and non-governmental initiatives. Necessary security guarantees: The functioning of legal and executive mechanisms should be ensured for the physical safety, property rights and protection of cultural heritage

of the population returning to the territories [3]. In this context, the sustainability of peace and the success of reintegration are possible only with mutual agreement and compliance with international law.

Gradual resolution of the issue in the process of normalization with Armenia. The process of normalization of relations with Armenia creates an important window of opportunity for a peaceful and gradual resolution of the West Azerbaijan issue. The rights of Azerbaijani Turks deported from West Azerbaijan should be included as a separate agenda item in the negotiations between the parties. For this process to be carried out effectively: Determination of legal and political mechanisms in the peace agreement: The right of return and the practical guarantee of this right should be reflected in relevant legal documents. Development of a stage-by-stage return model: At the first stage, it is

important to select pilot regions and villages, accompany them with infrastructure planning and security measures. Legal resolution of property and property issues: Special mechanisms should be created regarding properties lost as a result of deportation, and compensation or restoration options should be discussed. Legal recognition of the West Azerbaijan issue and Armenia's demonstration of a constructive position within the framework of the normalization process may be possible with the support of the international community.

Activities of the West Azerbaijan Community. The West Azerbaijan Community began to take shape in 1989, but since 2022, upon the initiative of President Ilham Aliyev, it has become an important public organization operating at the state level, taking on an official and institutional character. The main goal of the community is to protect the rights of our compatriots deported from West Azerbaijan, plan the return process, and carry out activities based on international law in this direction. The community's areas of activity include the following: Preparation of the Return Concept and compilation of documents based on international law; Activities of research and information collection centers, documentation of historical facts and deportation processes; Cooperation with the diaspora, raising the issue of West Azerbaijan at international events; Awareness and propaganda work, especially holding events to involve the younger generation in this topic. These activities serve to strengthen national unity in Azerbaijani society, and to recognize the legal and political position of the deported population at the international level

The role of the Azerbaijani diaspora in this direction. The Azerbaijani diaspora, especially diaspora organizations located in Europe, the USA and Turkey, play an important role in communicating the issue of Western Azerbaijan to the international community and in lobbying activities. The activities of the diaspora are of particular importance in the following areas: Establishing relations with foreign political circles and presenting the issue to members of parliament and government bodies; Implementing broad awareness campaigns on multinational media and social platforms; Cooperation with international legal experts and human rights organizations; Scientific and public substantiation of the issue by organizing academic and cultural events. These activities ensure that the diaspora supports the international diplomacy of the Azerbaijani state and that the issue of Western Azerbaijan remains on the agenda of international politics.

Preservation of historical memory and informing new generations. The issue of Western Azerbaijan is not only a political and legal problem, but also a matter of collective historical memory. Preserving historical memory and passing it on to future generations plays an important role in preserving national identity. For this purpose, it is important to work in the following areas: Including topics related to Western Azerbaijan in educational programs and textbooks; Organizing seminars, competitions, scientific conferences and summer schools for young people; Preparing literary and artistic examples, documentaries, theatrical performances, conveying historical facts in an emotional and artistic way; Creating and sharing educational content on social media, especially focusing digital literacy on this area among young people. These areas contribute to the formation of public consciousness and keeping alive the idea of historical justice.

Documentation and dissemination of cultural heritage. Thousands of material and cultural monuments belonging to Azerbaijani Turks, including mosques, cemeteries, tombs, ancient settlements, stone inscriptions and toponyms, are located in the territories of Western Azerbaijan. A significant part of this heritage has been destroyed, and some has been Armenianized. Therefore: Systematic documentation of historical and cultural heritage, collection and digitization of maps, archival documents and photo and video materials are important; Preparation of international reports on cultural heritage and submission to organizations such as UNESCO, activation of international legal mechanisms for the protection of heritage; Creation of virtual museums, web archives and interactive platforms can provide access to this heritage for both scientists and the general public. All these activities are of strategic importance in terms of both transferring historical facts to future generations and attracting the attention of the international community to the acts of vandalism committed by Armenia against cultural heritage.

International activities of the West Azerbaijan Community. The West Azerbaijan Community is active not only within the country, but also internationally. One of the main goals of the community is to introduce the rights of our compatriots deported from West Azerbaijan to the international community, to put this issue on the international agenda as a legitimate legal and political issue.For this purpose, the community: Prepares appeals to international organizations and human rights institutions; Submits reports documenting the facts of deportation and ethnic cleansing; Creates dialogue platforms with the international community, organizes events and forums; Holds scientific and theoretical conferences on the cultural heritage of West Azerbaijan and the history of deportation. The activities of the community, carried out synchronously with the diplomatic initiatives of the Azerbaijani government, allow the problem to be presented at the international legal level [29].

Legal and humanitarian cooperation with international organizations. Purposeful cooperation with international organizations is necessary for the recognition and support of the West Azerbaijan issue in the context of international law. This cooperation can be expanded in the following directions: introducing the right of return and launching legal mechanisms through the UN and its relevant agencies (UNHCR, OHCHR); organizing hearings on the issue in the Council of Europe and the European Parliament and initiatives for the adoption of resolutions; achieving the adoption of acts of solidarity within the framework of organizations such as the Organization of Islamic Cooperation (OIC) and the Non-Aligned Movement; cooperation with cultural heritage organizations such as UNESCO and ICOMOS, registering and protecting destroyed and falsified cultural monuments in West Azerbaijan; conducting joint investigations with interna-

tional lawyers and legal organizations and preparing legal claims for international courts. Working with the international community in this context is important both in terms of creating legal responsibility and promoting the political and humanitarian status of the problem at the global level [21].

Preservation of historical memory and informing new generations

The issue of Western Azerbaijan constitutes an important part of the collective memory of the Azerbaijani people. In order to preserve historical memory and pass it on to future generations, the following measures are being taken: Including topics related to Western Azerbaijan in textbooks in schools and higher education institutions; Organizing scientific conferences, seminars and projects to research and present historical facts; Preparing documentaries, books, multimedia projects and other educational materials to educate new generations; Holding competitions, exhibitions and events to strengthen the sense of patriotism and national identity among young people. As a result of these measures, the continuity of the issue of Western Azerbaijan is ensured and the involvement of the younger generation in the struggle for historical justice is ensured. The historical and cultural heritage of the Azerbaijani Turks living in Western Azerbaijan is rich and diverse. However, this heritage has been systematically destroyed or falsified by the Armenians. Therefore, the protection of cultural heritage and its dissemination to the international community is one of the important priorities. The work carried out in this direction is as follows: Documentation, digitization and mapping of historical and cultural monuments, mosques, cemeteries and other cultural heritage samples; Submission of appeals and reports to international organizations for the protection and restoration of cultural heritage; Disseminating this heritage to a wide audience through the creation of virtual museums and interactive platforms; Introducing the historical heritage and the facts of deportation to the world through multimedia projects and social media campaigns. These activities serve both to protect national identity and to increase responsibility for Armenia's cultural vandalism at the international legal level.

Challenges and Perspectives

Regional and international political situation. One of the main challenges affecting the resolution of the issue of return to Western Azerbaijan is the political dynamics existing in the region and at the global level. The South Caucasus region is characterized as a place where both geopolitical conflicts and the interests of great powers intersect. The different strategies and rivalries of Russia, Turkey, Iran and Western states in the region directly affect the pace and content of the return process. In such conditions: Regional security and stability issues have not yet been fully met; Different geopolitical goals of great powers lead to different tactics and priorities in approaching the issue of return; The attention of the international community is mainly focused on Nagorno-Karabakh and other border conflicts, which prevents the issue of Western Azerbaijan from receiving sufficient attention. These factors complicate the resolution of the issue of Western Azerbaijan in the international legal context and require a multifaceted strategic approach [5].

Political positions within Armenia. The attitude towards the West Azerbaijan issue within Armenia is mainly negative and cautious. Some political forces in the country assess the open discussion of the issue as a risk to the peace process and prefer to preserve the status quo. On the other hand, certain political circles and some parts of the public want the issue to be used in regional and international diplomacy. This situation: creates internal political fragmentation in Armenia, which prevents a constructive solution to the issue; makes it difficult for the West Azerbaijan issue to become a turning point in Armenian policy; slows down the establishment of mutual trust and finding territorial compromises in the peace process. This uncertainty in Armenia's internal policy is one of the main challenges in resolving the West Azerbaijan issue [7].

The role of this issue in the Azerbaijan-Armenia peace process. The West Azerbaijan issue is both sensitive and strategic in the peace process between Azerbaijan and Armenia. In the negotiations on the peace treaty, this issue: is in a priority position as ensuring the right of return within the framework of the full restoration of Azerbaijan's sovereignty and territorial integrity; acts as a key component in the resolution of mutual security guarantees and humanitarian issues; The development and implementation of phased and transparent return plans is essential for the process to be successful. In this context, resolving the West Azerbaijan issue through a constructive and realistic approach in the peace process can ensure long-term stability and open up new opportunities for mutual understanding in the region [8].

Restoration and documentation of historical-geographical memory. Restoration and documentation of historical-geographical memory in the West Azerbaijan issue is of strategic importance for the protection of national identity and justice. The main goal of this process is the systematic collection, archiving and digitization of facts related to the historical territories of the region, toponyms, material and cultural heritage and events related to deportation. The work carried out in this direction includes the following activities: Collection and study of archival documents, including statistics, settlement documents and deportation protocols from the Soviet era; Creation of a digital database of historical maps, photographs and field studies; Mapping the geographical location of toponyms and historical monuments, as the main source for the restoration of the ethnic and cultural landscape of the region; Organization of academic research and documentary publications, cooperation with international scholars in this field. This documentation process ensures the presentation of the West Azerbaijan issue on an objective and factual basis, both at the local and international levels [17].

Propaganda and information struggle in foreign media. A purposeful propaganda and information struggle should be carried out in order to present the issue of Western Azerbaijan correctly and balancedly in the international media space. This struggle, in addition to reacting to Armenia's attempts to distort and falsify the topic, is to convey the true voice of Azerbaijan

to the world. The main tasks to be carried out in this direction are as follows: Organizing information campaigns in international media, preparing and distributing positive and factually based news and analytical articles; Active activity on social media platforms, providing fact-based responses to false information, creating video and multimedia content; Preparing resources in foreign languages (English, Russian, French, etc.), bringing the issue to a wider audience; Involving experts in the field of information warfare, preparing and implementing strategies. Activities carried out in this direction serve to form international public opinion, support Azerbaijan's rightful position, and better understand the issue of Western Azerbaijan in the international arena [15].

Necessary conditions for return. One of the main conditions for the successful implementation of the return process to Western Azerbaijan is the full provision of political and diplomatic preparation. At this stage: creating and strengthening trust between Azerbaijan and Armenia; supporting the issue on a legal level in the international community, recognizing the right of return in the peace process; providing guarantees of peace and security through international organizations; preparing and agreeing on phased return plans in diplomatic negotiations is important. This political and diplomatic preparation ensures that the return process is carried out on the basis of mutual agreement and in conditions free from violence [3].

Restoration of property rights. One of the main legal issues during the return of internally displaced persons is the restoration of their lost property rights. The following measures are important in this direction: Registration of lost property and recognition of ownership rights; Establishment of mechanisms for the restoration or compensation of property; Simplification of legal procedures and ensuring transparency; Organization of the activities of independent and fair bodies for the resolution of judicial and administrative disputes. These conditions are vital for improving the socio-economic status of IDPs and protecting their rights [14].

Infrastructure and reintegration plans. In order for the return to be sustainable and safe, it is necessary to reconstruct the infrastructure in the areas and prepare reintegration plans. The main directions in this area are: Restoration of housing and social infrastructure (roads, electricity, water, education and health facilities); Promotion of economic activities, creation of jobs and preparation of social support programs; Provision of psychological and social services to support the reintegration process; Taking appropriate legal and physical measures to ensure the safety of the population.The phased implementation of infrastructure restoration and reintegration plans ensures the effectiveness and long-term stability of the return process [4].

Conclusions and Recommendations

The issue of return to Western Azerbaijan is not only a regional problem, but also a complex issue that combines international law, humanitarian and geopolitical aspects. It is important to establish a sustainable, multifaceted and coordinated strategy in solving this problem. It is necessary for the return strategy to be sustainable and multifaceted. Strengthening the legal basis, conducting political-diplomatic initiatives, and forming cultural and public awareness should be considered as complementary elements. Such a strategy allows us to see the return process not only as territorial restoration, but also in a broader context such as social integration, security and restoration of historical justice.

The importance of coordinated activity on the legal, diplomatic and public fronts should be particularly emphasized. Synchronized cooperation between state institutions, the West Azerbaijan Community, the Azerbaijani diaspora and international partners will increase the effectiveness of return. This coordination will strengthen both legal protection and information struggle, and will provide support from the international community. Ultimately, a successful resolution of the Western Azerbaijan issue will ensure long-term peace and regional stability, and will pave the way for the full restoration of Azerbaijan's territorial integrity and the implementation of national justice.

Strategic Roadmap Proposal. It is necessary to develop an effective and realistic roadmap for resolving the issue of return to Western Azerbaijan. This roadmap should include a multifaceted, phased and flexible approach, so that both legal, political and humanitarian aspects are fully covered. The main elements of the roadmap are as follows:

Strengthening diplomatic negotiations and the recognition of the right of return within the framework of international law;

Ensuring mutual security and humanitarian guarantees between Armenia and Azerbaijan;

Establishing mechanisms for the restoration of property rights and compensation;

Phased implementation of infrastructure reconstruction and social reintegration programs;

Public awareness, protection of cultural heritage and restoration of historical memory;

Strengthening cooperation with the diaspora and international organizations;

Ensuring information security and implementing effective communication strategies against misinformation.

Importance in terms of Regional Stability and Long-Term Peace. The implementation of this strategic roadmap will directly impact on ensuring long-term peace and stability in the region. A fair and legal solution to the West Azerbaijan issue will:

Contribute to the restoration of mutual trust in the region and the strengthening of the peace process between the parties;

Create conditions for the reduction of tensions on ethnic and political grounds;

Create a favorable environment for the development of economic integration and cooperation in the region;

Support the balancing of the strategic interests of the great powers in the region;

Ensure the implementation of human rights and international humanitarian law principles by restoring the rights of internally displaced persons.

In this regard, the roadmap will lay the foundation for peace and prosperity for both Azerbaijan and Armenia, as well as the entire South Caucasus region [18].

References:

1. Akçam, T. (2012). *The Young Turks' Crime Against Humanity: The Armenian Genocide and Ethnic Cleansing in the Ottoman Empire*. Princeton University Press.
2. Barkey, H. J. (2008). *Empire of Difference: The Ottomans in Comparative Perspective*. Cambridge University Press.
3. Cassese, A. (2001). International Law. Oxford University Press.
4. Cernea, M. M. (1997). The Risks and Reconstruction Model for Resettling Displaced Populations. World Development, 25(10), 1569–1587. https://doi.org/10.1016/S0305-750X(97)00062-3
5. Cornell, S. E. (2017). The Nagorno-Karabakh Conflict. Uppsala University.
6. Chapman, N. J. (2005). *Return and Reconstruction in Post-Conflict Settings: Refugee Return and Reintegration in Bosnia and Herzegovina*. Journal of Refugee Studies, 18(3), 340–359. https://doi.org/10.1093/jrs/fei029
7. De Waal, T. (2020). Nagorno-Karabakh: Anatomy of a Frozen Conflict. Brookings Institution Press.
8. Ganguly, S., & Schell, P. (2019). The Nagorno-Karabakh Conflict: History, Dynamics, and Prospects for Peace. Routledge.
9. Gomez Isa, F. (2006). "The Right to Return of Refugees and Internally Displaced
10. Gunter, M. M. (2011). *The Kurds: A Modern History*. Markus Wiener Publishers.
11. Horowitz, D. L. (2001). *The Deadly Ethnic Riot*. University of California Press.
12. Janz, A., & Ollier, G. (Eds.). (2017). *Displacement and Dispossession in the Modern Middle East*. Berghahn Books.
13. Kaldor, M. (2013). *New and Old Wars: Organized Violence in a Global Era*. Stanford University Press.
14. Kritz, N. J. (2001). *Engaging Countries in Post-Conflict Reconstruction*. United States Institute of Peace Press.
15. Nye, J. S. (2010). Public Diplomacy and Soft Power. *The Annals of the American Academy of Political and Social Science*, 616(1), 94–109. https://doi.org/10.1177/0002716210369374
16. Shain, Y., & Barth, A. (2003). Diasporas and International Relations Theory. International Organization, 57(3), 449–479. https://doi.org/10.1017/S0020818303573033
17. Smith, A. D. (2006). The Ethnic Origins of Nations. Wiley-Blackwell.
18. Stein, A. (2018). Conflict Resolution and Peacebuilding in the South Caucasus. Palgrave Macmillan.
19. Lederach, J. P. (1997). *Building Peace: Sustainable Reconciliation in Divided Societies*. United States Institute of Peace Press.
20. Richmond, O. P. (2014). *The Transformation of Peace*. Palgrave Macmillan.
21. Wolff, S. (2011). *Conflict Management in Divided Societies*. Routledge.
22. United Nations. (2018). *Guiding Principles on Internal Displacement*. United Nations Office for the Coordination of Humanitarian Affairs (OCHA).
23. United Nations High Commissioner for Refugees (UNHCR). (1997). *The State of the World's Refugees*. Oxford University Press.
24. United Nations. (1948). Universal Declaration of Human Rights. Retrieved from https://www.un.org
25. UN General Assembly. (1966). International Covenant on Civil and Political Rights.
26. UN Commission on Human Rights. (1993). Report on the Human Rights Dimensions of Population Transfer, E/CN.4/Sub.2/1993/15.
27. UNHCR. (2019). *Global Trends: Forced Displacement in 2018*. UNHCR Report.
28. Zartman, I. W. (2000). *Ripeness: The Hurting Stalemate and Beyond*. In P. Stern & D. Druckman (Eds.), *International Conflict Resolution After the Cold War* (pp. 225–250). National Academies Press.
29. Qərbi Azərbaycan İcması. (2022). Qayıdış Konsepsiyası. Bakı.

PSYCHOLOGICAL SCIENCES

ANALYSİS OF THE RELATİONSHİP BETWEEN İNTERNET ADDİCTİON AND PSYCHOLOGİCAL SYMPTOMS İN STUDENTS

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Abstract

The Internet, the most flexible and optimal means of information exchange, emerged in the middle of the 20th century and began to develop rapidly all over the world. In fact, the use of the Internet, as in many areas of society, has created favorable conditions for the computerization of training in education and the application of new training methods on this basis. It is known that the Internet is an indispensable tool that allows schoolchildren to broaden their worldview, increase cognitive capabilities, and obtain information more easily and quickly. However, along with its significant positive impact, the Internet has also created conditions for the emergence of a number of negative situations. Thus, like other modern means of communication, the Internet has caused a number of problems and led to a number of shortcomings in the system of human relations, the educational process, and in various areas of society. In this regard, studying the negative aspects of the Internet is more relevant today. Some experts point out that one of the negative aspects of the Internet is that users can easily access immoral images, texts and pornographic images. In fact, this aspect is the most obvious aspect of the problem at first glance. A comprehensive study of the problem requires penetrating into the deeper layers of its negative aspects and developing important preventive measures on this basis. Conducted psychological studies show that the most serious problem created by the Internet for schoolchildren and educational subjects is internet addiction, and Internet addiction (dependence) causes serious problems in the educational and family relationships of users, complicates the organization of educational work, and creates obstacles to the optimization of training. Thus, if a user cannot tolerate not using the Internet for a month, then we can claim that he is already facing the threat of Internet addiction. Unfortunately, this problem has been observed more often among schoolchildren recently.

Keywords: internet addiction, children, school, dependence, problems

The psychological problems caused by Internet addiction make it as dangerous as other addictions, and the implementation of the plan of measures is an important task. The development of technology not only causes a number of problems for Internet and computer users, but also increases previous problems, and causes a number of negative manifestations in the psychological plan. Despite the quick access to necessary information with the help of the Internet and its positive aspects, the advantages of the Internet overshadow the negative effects it causes.

However, it should be taken into account that virtual addiction or Internet addiction of users causes very serious socio-psychological problems, negatively affects the behavior of users, creates disharmony in their social relationships, and increases depressive states. In this regard, the study of the negative effects of the Internet and the problems it creates is very relevant for the modern era. Despite the studies conducted by psychologists and educators, it cannot be said that the problem has been completely solved. While examining the history of the study of Internet addiction in psychology, we found that the mentioned problem was studied in different directions. In psychology, Internet use and extreme deviations during use, and finally the manifestation of Internet addiction, have been evaluated as a current problem and studied in different directions.

In addition to a number of factors, the emergence of Internet addiction in schoolchildren is also seriously affected by their general health level, emotional state, self-confidence and self-awareness. In accordance with the main hypothesis, several auxiliary hypotheses were also taken:

• There is a relationship between Internet addiction of schoolchildren and their physical health.

• There is a relationship between Internet addiction of schoolchildren and their depression.

• There is a relationship between Internet addiction of schoolchildren and their social activity.

When we talk about adolescent psychology, we first examine the characteristics of the mental development of adolescents. Thus, adolescence covers the period between childhood and adulthood. Usually, adolescence is considered as a transition stage from childhood to adulthood. In fact, adolescence can be viewed as a bridge connecting childhood and adulthood that everyone can cross. But how are the boundaries of adolescence formed? Psychologists believe that adolescence consists of 3 different stages: early adolescence (ages 11-14), middle and late adolescence (ages 15 to 18). In contrast, some researchers believe that since adolescence has its own unique characteristics, each teenager participates in this process subjectively and physiologically. development can support psychological development, but in some cases these processes are not properly completed, and thus various behavioral disorders appear.

During this age period, a fundamental change occurs in the biological maturation of the child's body. In the upper and lower extremities, the bones grow longitudinally faster than the muscles. The extremities of the body lose their proportion to the trunk and appear

longer. Height growth is very rapid, sometimes increasing by 8-10 cm in a year. In general, the development of the body in boys and girls is different at different ages. Thus, in girls, breast development begins at 10-12 years of age, after which hair appears in the genital area and under the armpits, and menstruation begins within the next 2 years. Menstrual bleeding can begin between 10-16 years of age, and irregular bleeding occurs especially in the first years. Rapid height growth occurs within 1 year after the onset of signs of puberty. Girls, who are shorter than boys on average during childhood, take their first steps towards growth at 10-12 years of age and are generally taller and heavier at this time. They reach their maximum height at 16-17 years of age.

During this age period, special changes also occur in the psychosexual development of adolescents. The onset of sexual maturation during this period plays a kind of starting point for sexual maturity. At the same time, appropriate conditions are created for psychological maturity, as well as social maturity.

In the discovery of the mechanism of adolescence, the prominent psychologist A.N. Leontiev's statement that the driving force of a child's mental development is a change in the real place he occupies in the system of social relations is of great importance [8].

There are various approaches to adolescence in the psychological literature. As we have said earlier, studying the psychological characteristics of adolescence is one of the important issues. Therefore, first of all, let us consider various approaches to adolescence. First, let us pay attention to the biological approach. According to the supporters of this point of view, the main issue in adolescence is the study of the processes of sexual maturation and physical development.

Changes in the relationships, emotional reactions, and health of adolescents are directly related to the onset of puberty.

According to biologists, the main source of the main changes is biogenetic factors. These factors play an important role in the psyche and behavior of adolescents. It is believed that the behavior of a teenager, his growth, is controlled by the internal energy of sexual maturation, and the socio-cultural conditions of his upbringing are of an insignificant nature.

One of the most prominent representatives of the theory of the biological approach is Stanley Hall. For the first time in the USA, he studied the period of adolescence, investigated its psychological characteristics. Unlike modern theorists, S. Hall believes that adolescence is a period of difficult emotional adaptation and imbalance. Frequent mood swings, apathy, self-importance and seriousness are characteristic features of a teenager [4].

One of the directions of studying the period of adolescence in its own aspect is psychoanalysis. It can be said that these directions have been analyzed at the appropriate level, unlike others. According to Freudianism, adolescence is a period of sexual maturation, excitement and manifestation of abnormal behavior. Z. Freud especially emphasizes two elements in the sexual interests of teenagers and young people: a) physical, emotional; b) mental[2].

A number of researchers have proven that the formation of personality depends not only on biological, but also on sociological and psychological factors (Margaret Mead).

One of the theories that explains a number of aspects of adolescence differently from others is social psychoanalysis. Its founder is Erik Erikson. According to him, the main feature of a teenager is his positive self-identification. This can manifest itself in identical criminal behavior.

Many researchers characterize adolescence as a "transitional period" (from childhood to youth), a "difficult period" (for teachers and parents), a "turning period" and a "crisis period". In fact, the truth is this: a child moves from one stage of his life to another, from childhood to adulthood.

We would also like to write about the contradictions that occur during adolescence. Regarding the contradictions of the adolescent personality, A. Freud noted that "Adolescents are extremely selfish, they consider themselves the center of the universe and the only being worthy of attention, but at the same time, at no later stage of their lives are they capable of such loyalty and self-sacrifice. They enter into passionate love relationships only to end them as suddenly as they began them. On the one hand, they enthusiastically join the life of society, and on the other hand, they are enveloped in a feeling of loneliness. They hesitate between blind obedience to the leader and any rebellion against authority. They They are selfish and materialistic. At the same time, they worship the sublime and idealistic. They are ascetics, but at the same time they can fall into the most primitive depression. Despite their extreme fragility, they sometimes show rudeness towards other people" [3].

A number of contradictory moments emerge in the transition from childhood to adulthood. During this age period, childhood experiences its end and a sense of adulthood begins to manifest. The transition to adulthood manifests itself from various sides. Here, a specific change in anatomical, physiological, intellectual and moral development occurs. Along with all this, serious changes are also manifested in the type of activity and living conditions of the schoolchild, and these changes create conditions for the restructuring of the psyche and the emergence of new forms of attitude towards people.

It should not be overlooked that adolescence is the most complex period of human ontogenetic development. On the one hand, this age period is a transitional period, that is, the transition from childhood to youth. At this time, a number of biological and psychophysiological changes occur in the body, and at the same time, the process of self-awareness and self-evaluation of the teenager becomes more intense. A number of contradictions manifest themselves in this process. Among such contradictions, the teenager's relatively rapid physical development, that is, the disproportionate development of body parts, and his attitude towards himself and the discrepancy between his ideas about himself plays an important role. Also, the discrepancy between the increase in his physical capabilities and his intellectual capabilities, that is, he gets tired of intellectual activity more quickly than physical movements, is

manifested. The most important thing is that despite his physical growth and intellectual development, his social position, that is, the attitude towards him (whether by parents or teachers), has not yet changed at the necessary level, he is still treated as a child, he does not believe in him properly, does not show trust.

When talking about the process of the appropriate formation of the adolescent personality, the general level of development of society, the socio-economic situation, modern historical conditions and the qualities inherent in modern adolescents, as well as individual-typological characteristics, should be taken into account. The driving forces of development during adolescence are both external contradictions occurring between the adolescent personality and the environment, and internal contradictions.

Quite diverse demands are made on the adolescent. These demands, especially when the demands of the collective do not coincide with the demands of individual people, when the environment surrounding the adolescent fundamentally differs from the school environment, A conflict arises between a teenager and the outside world. For example, if the demands made by the school to a teenager are not supported by the family, if he is given one kind of demands at school and another in the family, the conflicts between him and the teachers are resolved by slowing down, gradually weakening and abolishing old customs. Or it may be that the teenager is resolved by his own intellectual or, conversely, by the decrease in the teenager's demands on himself.

Internal conflicts cause uneven development of individual qualities and aspects of the teenager's personality. For example, the pace of perception and assimilation of knowledge is higher than the development of consciousness. Thus, a conflict arises between new knowledge and past knowledge, old ideas and new concepts, behavior and new requirements. These are not insoluble conflicts, but proper upbringing and favorable conditions resolve these conflicts.

Internal conflict can also arise between the teenager's inclinations and capabilities. For example, it happens that a teenager evaluates his own knowledge and abilities higher than they really are. Internal conflict is perceived by him as an external conflict. Correct upbringing affects him allows him to rise to the desired level. The contradiction between ability and character, between personal needs and moral duty is also of this kind.

The contradiction between the forms of cognition is also an internal contradiction. For example, if there is no unity between the teenager's feelings and logical cognition, he, as a rule, opposes his personal experience to the regular course of events, evaluates everything in terms of concrete facts. Sometimes he even goes to the extreme of opposing the knowledge he has gained as a result of personal experience to scientific knowledge. The contradiction between reason and feelings is resolved by objective analysis of facts and events and correct generalization.

Internal contradiction also arises when the natural capabilities of the teenager and the qualities he has acquired in life do not match each other. For example, a teenager with a choleric temperament type in his behavior tries to restrain his feelings, sometimes regrets when he gets excited and loses his temper, and tries to behave with restraint. Or, although a teenager with a melancholic type wants to be optimistic and courageous in all situations, his shyness and indecision prevent him from These contradictions are resolved by strengthening the will and developing volitional qualities.

Youth Another important contradiction that is more clearly noticeable during the Melik period and is sharply expressed in its behavior and actions is the discrepancy between the teenager's desires and wishes and his social position. All these discrepancies and contradictions are reflected in one way or another in the emotional-volitional characteristics, behavior and attitudes, and the system of relationships of teenagers.

References:

1. Guliyev R.M. Sociology: Theory and research methodology: (Monography). Baku, Siyasat, 1995, 423 p.

2. Gudsi Faranak Bahaddi “Comparative social-psychological analysis of the behavior of schoolchildren using the Internet” (Tehran - Baku) Abstract of the dissertation submitted for the degree of Doctor of Philosophy in Psychology, Baku - 2016, 24 p.

3. Psychology. Textbook for undergraduate students of higher pedagogical schools. With the scientific editorship of Prof. S.I. Seyidov and Prof. M.A. Hamzayev. Baku, 2007.)

4. Shafiyeva E. I. Clinical psychology. - Baku.: BSU Publishing House, 2002. - 81 p.

5. Shafiyeva E. I. Psychological problems of the clinic of somatic diseases. Baku, 2013, 195 p.

6. Aydoğdu C. Psychological effects of television and computer (18-24 years old) on young people: the example of Hendek. Unpublished Master's Thesis, Sakarya University Social Sciences Institute, Sakarya, 2003.

7. Bandler R. Eskimo change. Istanbul, Ganj publishing house, 2009, 238 p.

8. Bayraktar, F. The role of Internet use in adolescent development. Unpublished Master's Thesis, Ege University, Institute of Social Sciences, Izmir, 2001.

9. Ceyhan E., Ceyhan A.A. and Gurcan, A. (2007). Validity and reliability studies of the problematic internet use scale. Journal of Educational Sciences in Theory and Practice (KUYEB), 7, 387-416.--additional book

10. Diğdem M. Siyez, Erol Esen Analysis of Psycho-social Factors Contributing to Internet Addiction in Adolescents. Turkish Journal of Psychological Counseling and Guidance. 2011, 4 (36), pp. 127-138.

SOCIAL SCIENCES

THE USE OF ARTIFICIAL INTELLIGENCE IN SOCIAL WORK

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ПРИМЕНЕНИЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В СОЦИАЛЬНОЙ РАБОТЕ

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Abstract

The article examines the possibilities and key areas of applying artificial intelligence in social work in the context of the digitalization of the social sector. It analyzes the main artificial intelligence technologies used to assess clients' needs, predict social risks, improve the efficiency of social services, and support professional decision-making by social workers. Special attention is paid to ethical issues, data confidentiality, and the risks of algorithmic discrimination. Based on an analysis of contemporary research, the article substantiates the potential of artificial intelligence as a tool for enhancing the quality and accessibility of social assistance while preserving the humanistic values of social work.

Аннотация

В статье рассматриваются возможности и направления применения искусственного интеллекта в социальной работе в условиях цифровизации социальной сферы. Анализируются основные технологии искусственного интеллекта, используемые для оценки потребностей клиентов, прогнозирования социальных рисков, повышения эффективности социальных услуг и поддержки профессиональных решений социальных работников. Особое внимание уделяется этическим аспектам, вопросам конфиденциальности данных и рискам алгоритмической дискриминации. На основе анализа современных исследований обосновывается потенциал искусственного интеллекта как инструмента повышения качества и доступности социальной помощи при сохранении гуманистических ценностей социальной работы.

Keywords: artificial intelligence, social work, social sphere, social risks, digitalization of the social sector, data confidentiality, ethics, social services.

Ключевые слова: искусственный интеллект,социальная работа,социальная сфера,социальные риски. цифровизация социальной сферы, конфиденциальность данных, этика,социальные услуги.

Хотя это не всегда очевидно, искусственный интеллект уже давно стал неотъемлемой частью повседневной жизни миллионов людей. Искусственный интеллект может поддерживать человека в самых разных сферах - хотя бы тем, что делает жизнь более удобной. Однако, когда на сцену вышел генеративный ИИ, такой как ChatGPT, его удивительная способность имитировать человеческие реакции и доступность для каждого, у кого есть компьютер, неожиданно вывели дискуссии о машинном обучении и соблюдении этических норм в публичную сферу. Такие понятия, как глубокое обучение, NLP и нейронные сети, просочились в повседневные профессиональные и даже личные разговоры.

По своей сути искусственный интеллект - это способность машины или компьютерной системы выполнять задачи, для которых обычно требуется человеческий интеллект. Это включает в себя программирование систем для анализа данных, обучения на основе опыта и принятия разумных решений - под руководством человека. Наиболее известной формой ИИ являются виртуальные помощники, такие как Siri или Alexa, но существует множество разновидностей данной технологии. ИИ способен произвести революцию в различных отраслях, позволяя машинам решать сложные задачи и мыслить интуитивно, выходя за рамки простой автоматизации. ИИ включает в себя различные области и технологии, такие как машинное обучение и обработка естественного языка.

Искусственный интеллект, способный синтезировать, анализировать и действовать на основе огромных объемов данных за считанные секунды, является чрезвычайно мощным. Как и в случае с любой другой мощной технологией, очень важно ответственно подходить к ее внедрению, чтобы максимально использовать ее потенциал и при этом минимизировать негативные последствия. [1;cc.10-13]

Например, при обучении на непроверенных данных искусственный интеллект может копировать негативные предрассудки о расе, религии, воспитании и других характеристиках человека. Такие случаи могут стать потенциально опасными, если искусственный интеллект будет использоваться в здравоохранении, подборе персонала, юриспруденции и других сферах, ориентированных на человека.

В социальной сфере стали широко применяться цифровые технологии, меняющие способы взаимодействия государства, общества и граждан различных возрастных групп, а также данные технологии направлены на улучшение качества обслуживания населения, оптимизацию административных процессов, повышение прозрачности системы социальной помощи и др. Современный период цифровой трансформации требует осмысления и изучения опыта применения ИИ в социальной сфере.

Социальное **воздействие ИИ** выходит далеко за рамки непосредственного решения проблем. При ответственном внедрении ИИ может привести к системным изменениям, улучшая возможности принятия решений, оптимизируя распределение ресурсов и демократизируя доступ к информации**,** которая ранее была доступна только привилегированным группам населения. Для некоммерческих организаций и организаций развития, работающих с ограниченными бюджетами и обслуживающих огромные группы населения, ИИ представляет собой возможность масштабировать воздействие, сохраняя при этом экономическую эффективность.

Маргинализированные группы населения часто лишены доступа к рынкам, качественному образованию или надежному здравоохранению. Искусственный интеллект может стать инструментом выравнивания возможностей при грамотном применении.

Искусственный интеллект (ИИ) в социальной работе используется для автоматизации рутины, анализа больших данных, прогнозирования потребностей и персонализации поддержки уязвимых групп. ИИ помогает оптимизировать административные процессы, повышая скорость и точность оказания помощи, внедряя проактивный подход, при этом не заменяя человеческую эмпатию, а дополняя возможности специалистов. [10;с.72]

Применение искусственного интеллекта в социальной сфере охватывает несколько ключевых направлений, направленных на повышение эффективности помощи и автоматизацию рутинных процессов.

Основные направления:

Автоматизация госуслуг и администрирования:

- Ускорение проверки заявок на пособия и льготы.
- Автоматическое составление отчетов, протоколов встреч и ведение документации, что экономит до 40% рабочего времени сотрудников.
- Использование чат-ботов для круглосуточного информирования граждан.

Прогностика и ранняя помощь:

- Анализ данных для выявления рисков (например, прогнозирование вероятности бездомности или случаев насилия над детьми).
- Отслеживание изменений в поведении клиентов для раннего вмешательства (нарушение сна, пропуски приемов пищи).

Доступность и инклюзия:

- Инструменты распознавания и модификации речи для людей с инвалидностью или речевыми расстройствами.
- Машинный перевод для преодоления языковых барьеров при предоставлении услуг мигрантам.

Образование и занятость:

- Персонализация учебных планов и адаптивные программы обучения.
- Анализ трендов рынка труда для рекомендации курсов переквалификации и поиска подходящих вакансий.

Здравоохранение:

- Диагностика заболеваний (компьютерное зрение для анализа МРТ/КТ) и персонализация лечения. [3;сс.45-53]

Рассмотрим каждое направление подробно.

Автоматизация госуслуг и администрирования:

Интеграция ИИ в госуправление уже происходит, причем иногда — явочным порядком, еще до появления соответствующего регулирования или стратегий. Можно привести множество ставших повседневными (и не всегда позитивных) примеров из практики. В первую очередь это оптимизация взаимодействия граждан и государства, предполагающая использование ведомствами чат-ботов и голосовых помощников для автоматической обработки запросов граждан, а также создание умных платформ для предоставления госуслуг. Это распознавание лиц и силуэтов людей для полицейских нужд. Это умные города — управление транспортными потоками, энергопотреблением, мониторинг состояния окружающей среды. Далее, это уже проникающая в государственные системы здравоохранения диагностика медицинских заболеваний, анализ рентгеновских снимков и МРТ. Здесь же можно упомянуть моделирование стихийных бедствий, эпидемий и прочих кризисных ситуаций. Кроме того, в мире уже есть первый опыт построения модели социального управления на основе больших данных о поведении граждан (китайская система социального кредита).

Прогностика и ранняя помощь

Алгоритмы анализируют данные из разных источников (здравоохранение, жилье, соцслужбы) для выявления групп риска. Например, система *Allegheny Family Screening Tool* помогает определять высокий риск жестокого обращения с детьми еще на этапе поступления звонка на горячую линию.

Нейросети анализируют тональность заметок кейс-менеджера или сообщения клиента, чтобы обнаружить ранние признаки депрессии, суицидального поведения или одиночества. ИИ помогает создавать индивидуальные планы помощи, подбирая ресурсы под конкретные нужды клиента (например, раннее развитие ребенка от 0 до 6 лет). Чатботы (например, *Woebot* или *Wysa*) оказывают немедленную эмоциональную поддержку и помогают клиентам справляться с негативными мыслями до того, как ситуация перерастет в кризис. ИИ берет на

себя заполнение документации и составление писем-направлений, освобождая социальному работнику время для живого общения с клиентом.[7]

Доступность и инклюзия

Приложения вроде *Seeing AI* озвучивают текст, описывают предметы, распознают лица и валюту для незрячих клиентов. Сервисы автоматического субтитрования и перевода жестового языка в текст (и обратно) позволяют глухим людям полноценно общаться с соцработником без посредников. ИИ-синтезаторы голоса помогают людям с нарушениями речи (например, при ДЦП или после инсульта) выражать свои потребности. Инструменты для упрощения текстов («Plain Language») адаптируют сложные юридические документы для людей с ментальными особенностями или трудностями в обучении.

Нужно отметить, что при использовании искусственного интеллекта в инклюзии следует учитывать некоторые риски. Главная опасность — **«алгоритмическая предвзятость»**. Если ИИ обучался на данных, где люди с инвалидностью не были представлены, система может дискриминировать их (например, отсеивать резюме или ошибочно снижать рейтинг благонадежности).

Образование и занятость

Для интеграции ИИ в образовательную сферу необходимо оценить и откалибровать его текущие и потенциальные преимущества и риски таким образом, чтобы они приносили пользу академической среде. Такая интеграция возможна несколькими способами. Во-первых, ИИ может быть использован для автоматизации существующих полумеханических процессов, таких как оценивание работы студентов. В то время как уже существует множество менее сложных компьютерных программ для оценки стандартизированных заданий, таких как тесты с выбором ответа, ИИ может справляться с более сложными заданиями, включая эссе, вопросы с открытым концом и т.д. Он может как оценивать такие работы, так и предоставлять студентам полезную обратную связь. Более того, сокращение объема механической и полумеханической работы, выполняемой преподавателями, приведет к перенаправлению их времени на более эффективные занятия, такие как проведение занятий или разработка курсов. Это также положительно скажется на образовательных учреждениях, снижая общие затраты на предоставление образовательных услуг. Кроме того, автоматическая оценка с помощью ИИ обеспечивает последовательность и справедливость, устраняя потенциальные предвзятости, которые могут быть случайно допущены преподавателями. ИИ обладает огромным потенциалом в качестве инструмента персонализированного обучения. Технология может хранить и анализировать информацию о каждом студенте: их результаты, интересы, предпочтения, стили обучения, сильные и слабые стороны. На основе этой информации ИИ может предложить каждому студенту персонализированный образовательный путь, оптимизирующий и усиливающий процесс обучения. В сочетании с мгновенной обратной связью и пошаговыми инструкциями эти технологии способны сыграть роль высококвалифицированного и гибкого частного репетитора, обладающего бесконечным банком заданий, адаптированных к сильным сторонам студентов. Такая практика может значительно повысить академический потенциал каждого студента при значительно меньших затратах. Что касается рисков внедрения ИИ в образовательную систему, можно выделить три основных аспекта: конфиденциальность данных, дезинформация и человеческие отношения. [11;с.176]

Здравоохранение

Искусственный интеллект (ИИ) оказывает значительное влияние на медицину, улучшая работу врачей и эффективность клиник. В настоящее время нейросети активно используются для обработки медицинских изображений и помощи врачам в постановке диагнозов и выборе лечебной тактики. И открываемые ими возможности выглядят крайне перспективными. ИИ помогает в интерпретации рентгеновских снимков, МРТ и других изображений, что позволяет точно и быстро диагностировать различные заболевания, такие как рак различной локализации или переломы. Технологии машинного обучения способны обнаруживать детали, которые могут быть незаметны глазу человека. Искусственный интеллект (ИИ) все активнее применяется для профилактики и лечения заболеваний, предоставляя медицинским специалистам и пациентам новые инструменты для принятия решений. Одним из явных преимуществ ИИ является то, что он способен анализировать большие объемы данных, а также такие изображения, как МРТ и рентгеновские снимки, быстрее и иногда точнее, чем это могут делать врачи. Это особенно важно в тех областях медицины, где ограничены временные ресурсы и недостаточно персонала.

Использование ИИ требует сбора и анализа больших объемов медицинских данных, что ставит под угрозу конфиденциальность пациентов. Вопросы безопасности данных и уязвимости перед лицом кибератак являются значительным риском. Несмотря на эффективность ИИ в аналитических и диагностических задачах, он не может полностью заменить человеческий контакт и эмпатию, которые чрезвычайно важны в клинической практике. Разработка и внедрение ИИ требует значительных инвестиций, которые не могут позволить себе все медицинские учреждения, особенно в развивающихся странах. [9;сс.28-48]

Этические вызовы

Социальные работники, использующие или рассматривающие возможность использования ИИ, должны опираться на эти важные руководства и учитывать ряд ключевых этических соображений, касающихся информированного согласия и автономии клиента; конфиденциальности и защиты личных данных; прозрачности; ошибочной диагностики клиента; отказа от клиента; наблюдения за клиентом; плагиата, нечестности, мошенничества и искажения информации; алгоритмической предвзятости и несправедливости; а также использования инструментов ИИ, основанных на доказательствах. Эти ключевые этические концепции должны быть отражены в протоколах, разработанных с учетом

этических принципов и регулирующих использование ИИ социальными работниками.

Социальные работники всегда понимали свою обязанность объяснять потенциальные преимущества и риски услуг в рамках процесса информированного согласия. При использовании ИИ специалисты должны информировать клиентов о соответствующих преимуществах и рисках и уважать их собственное суждение о том, принимать или отклонять использование ИИ. Согласно Кодексу *этики* NASW (2021), «социальные работники, использующие технологии для оказания социальных услуг, должны получать информированное согласие от лиц, пользующихся этими услугами, во время первоначального скрининга или собеседования и до начала оказания услуг. Социальные работники должны оценивать способность клиентов давать информированное согласие и, при использовании технологий для общения, проверять личность и местонахождение клиентов». [6;сс.5-11]

Данные, собранные социальными работниками у клиентов с использованием ИИ, должны быть защищены. Социальные работники обязаны обеспечить надлежащее шифрование используемого ими программного обеспечения ИИ и его максимальную защиту от утечек данных. Социальные работники должны принимать меры для предотвращения неправомерного доступа к данным, сгенерированным ИИ, со стороны третьих лиц, например, поставщиков, спонсирующих используемое социальными работниками программное обеспечение ИИ. Согласно Кодексу *этики* NASW (2021), «социальные работники должны принимать разумные меры для защиты конфиденциальности электронных коммуникаций, включая информацию, предоставленную клиентам или третьим лицам. Социальные работники должны использовать применимые меры защиты (такие как шифрование, брандмауэры и пароли) при использовании электронных коммуникаций, таких как электронная почта, онлайн-публикации, онлайн-чаты, мобильная связь и текстовые сообщения». [12;сс.490-496]

В соответствии с устоявшейся концепцией информированного согласия в социальной работе, социальные работники, использующие ИИ, должны информировать клиентов о любом несанкционированном разглашении защищенной медицинской информации клиентов, например, в результате компьютерного взлома или сбоя в онлайн- или цифровой безопасности. Согласно технологическим стандартам, принятым NASW, ASWB, CSWE и CSWA (2017), «независимо от мер предосторожности, которые принимают социальные работники для обеспечения сбора, управления и хранения записей клиентов безопасным образом, конфиденциальные электронные записи могут быть скомпрометированы. Социальные работники должны соблюдать этические стандарты и соответствующие федеральные и государственные законы, касающиеся любой обязанности информировать клиентов о возможных нарушениях конфиденциальности. Социальные работники также должны разработать политику и процедуры, подробно описывающие, как они будут информировать клиентов о нарушениях конфиденциальности».

Клинические социальные работники, использующие ИИ для оценки проблем психического здоровья клиентов, должны предпринять шаги для минимизации вероятности ошибочной диагностики с помощью цифровых протоколов. Это может произойти, если социальные работники не дополняют свои оценки, полученные с помощью ИИ, собственными независимыми оценками и суждениями. Ошибочная диагностика может привести к неадекватным или необоснованным вмешательствам, которые, в свою очередь, могут нанести значительный вред клиентам и подвергнуть социальных работников риску судебных исков о врачебной халатности и жалоб со стороны лицензионных комиссий. По мнению Яна, Руана и Цзяна, «современный ИИ все еще далек от эффективного распознавания психических расстройств и не может заменить диагнозы врачей в ближайшем будущем». [8;сс.58-69]

Социальные работники, использующие ИИ для связи с клиентами, должны принимать меры для своевременного ответа на их сообщения и публикации, когда это необходимо. Используя юридический термин, социальные работники должны избегать «оставления» клиентов, которые используют ИИ для выражения значительного эмоционального стресса. В судебных разбирательствах по делам о профессиональной халатности оставление клиента происходит, когда специалисты не отвечают клиентам своевременно или прекращают оказание услуг способом, не соответствующим стандартам профессии. Например, клиент, который сообщает о суицидальных мыслях через ИИ, не получает своевременного ответа от своего социального работника и пытается покончить жизнь самоубийством, но выживает, может иметь основания для иска о профессиональной халатности. Согласно *Кодексу этики* NASW (2021), «социальные работники должны предпринимать разумные шаги, чтобы избежать оставления клиентов, которые все еще нуждаются в услугах. Социальные работники должны прекращать оказание услуг в экстренном порядке только при исключительных обстоятельствах, тщательно учитывая все факторы ситуации и принимая меры для минимизации возможных негативных последствий. Социальные работники должны оказывать помощь в организации надлежащих мер для продолжения оказания услуг, когда это необходимо». [5;сс.34-39]

Один из неотъемлемых рисков ИИ — возможность неправомерного и несанкционированного использования доступных данных третьими лицами в целях слежки. Например, социальные работники, оказывающие услуги в области репродуктивного здоровья клиентам в штатах, где аборты запрещены, должны учитывать возможность того, что прокуроры могут запросить электронно хранимую информацию (ЭПИ), созданную ИИ, для преследования беременных женщин, обращающихся за услугами по прерыванию беременности, и специалистов, помогающих им в принятии решения. Хотя

ЭПИ, находящаяся в распоряжении социальных работников, всегда могла быть обнаружена в ходе судебного разбирательства, возникает новая проблема, когда ЭПИ включает информацию, созданную ИИ (например, информацию о репродуктивном здоровье, созданную чат-ботами, используемыми клиентами и социальными работниками). Клиент или социальный работник, использующий ИИ для поиска в интернете информации об услугах, связанных с абортами, оставляет цифровой след. Согласно Федеральным правилам гражданского судопроизводства, ЭПИ определяется как любые документы или информация, хранящиеся в электронной форме.

Социальные работники, использующие ИИ, должны соблюдать действующие этические стандарты (NASW, 2021):

Социальные работники не должны участвовать в нечестности, мошенничестве или обмане, одобрять их или быть связанными с ними.

- Социальные работники должны брать на себя ответственность и признание заслуг, включая авторство, только за работу, которую они фактически выполнили и в которую внесли свой вклад.
- Социальные работники должны честно признавать работу и вклад других людей. (стандарт)

Технологии искусственного интеллекта развиваются стремительно. Передовые методы работы меняются с ошеломляющей скоростью. Социальные работники, внедряющие ИИ в свою практику, обязаны с этической точки зрения идти в ногу с научно обоснованными разработками и соответствующим образом корректировать свои протоколы. Ключевым ресурсом является Ассоциация содействия развитию искусственного интеллекта. Кодекс этики этой организации соответствует традиционным ценностям социальной работы. Согласно технологическим стандартам, принятым NASW, ASWB, CSWE и CSWA (2017), «технологии постоянно развиваются, как и их использование в различных формах социальной работы. Социальные работники должны быть в курсе доступных типов технологий и изучать передовые методы, риски, этические проблемы и способы управления ими». [4;сс.401-415]

Инициативы в области искусственного интеллекта должны придерживаться основных этических принципов, чтобы обеспечить ответственное проектирование и реализацию этих проектов. Ключевые принципы включают в себя:

- Технология искусственного интеллекта не причиняет вреда.
- Разработчики ИИ должны принимать меры для защиты клиентов и других лиц, которым они служат.
- Технология искусственного интеллекта разработана с использованием прозрачных протоколов и методологий, подлежащих аудиту.

Инструменты искусственного интеллекта собирают и обрабатывают данные клиентов для уменьшения предвзятости по отношению к группам населения на основе расы, этнической принадлежности, культуры, пола, сексуальной ориентации, гендерной идентичности, религии и других потенциальных источников предвзятости. Клиентов информируют об известных рисках и преимуществах технологий искусственного интеллекта, чтобы они могли принимать обоснованные решения об их использовании. В идеале, организации, которые нанимают социальных работников и используют ИИ, должны создать комитет по этике в цифровой сфере, состоящий из ключевых сотрудников, знакомых с цифровыми технологиями в целом, технологиями ИИ, а также существующими этическими стандартами и передовой практикой. Этот комитет должен осуществлять надзор за разработкой и внедрением ИИ. Фокус-группы, включающие представителей различных групп населения, от которых могут собираться данные для использования в ИИ, могут помочь уменьшить и предотвратить алгоритмическую предвзятость. В фокус-группы могут входить клиенты, защитники интересов клиентов, специалисты-практики, исследователи, преподаватели, лидеры сообществ, администраторы учреждений и политики. Они могут проанализировать существующие протоколы ИИ и предложить изменения для устранения рисков, связанных с алгоритмической предвзятостью. Строгие процессы экспертной оценки могут помочь выявить и устранить «слепые пятна» и слабые места в протоколах ИИ. В число экспертов могут входить социальные работники, знакомые с ИИ, исследователи, преподаватели и различные группы специалистов по анализу данных. Разработка имитационных моделей, проверяющих сценарии, в которых инструменты ИИ подвержены предвзятости, может быть полезна для снижения рисков и устранения возможной алгоритмической предвзятости. Обратная связь, полученная в результате моделирования, может выявить потенциальные этические проблемы, связанные с ИИ. Социальные работники должны быть обучены тому, как правильно использовать инструменты ИИ в качестве дополнения, а не замены профессионального суждения. Крайне важно, чтобы социальные работники понимали разницу между надлежащим и ненадлежащим использованием ИИ. В идеале организации, которые нанимают социальных работников и используют ИИ, должны вести всеобъемлющую базу данных, обобщающую результаты периодических тестов, чтобы выявлять сильные и слабые стороны своих протоколов ИИ. Со временем эту базу данных можно будет отслеживать для повышения эффективности ИИ и соответствия соответствующим этическим стандартам.

Наряду с широким спектром потенциальных преимуществ ИИ в социальной работе, возникает ряд серьезных этических проблем и рисков, особенно связанных с информированным согласием и автономией клиента; конфиденциальностью и защитой персональных данных; прозрачностью; неправильной диагностикой клиента; отказом клиента от обслуживания; слежкой за клиентом; плагиатом, нечестностью, мошенничеством и

искажением информации; алгоритмической предвзятостью и несправедливостью; а также использованием инструментов ИИ, основанных на доказательствах.

Для защиты клиентов и себя социальных работников следует предпринять ряд упреждающих шагов. Во-первых, им следует ознакомиться с протоколами ИИ и различными способами их использования в своей практике социальной работы. Во-вторых, социальным работникам следует пересмотреть соответствующие этические и практические стандарты, касающиеся использования ИИ, и убедиться, что их практика соответствует этим стандартам. В-третьих, социальные работники, занимающие руководящие должности, должны разработать и внедрить обучение для сотрудников по вопросам надлежащего и этичного использования ИИ в их рабочей среде. В-четвертых, образовательные программы по социальной работе должны включать в свои учебные планы материалы по ИИ, чтобы обеспечить ответственное использование ИИ следующим поколением социальных работников.

Первые специалисты в этой области и представить себе не могли, что сегодня социальные работники будут использовать технологии для удаленного обслуживания клиентов, вносить информацию о клиентах в электронные записи, хранящиеся в «облаке», и удовлетворять потребности клиентов с помощью искусственного интеллекта, а также других цифровых и электронных инструментов. Появление и распространение ИИ — еще одно напоминание о том, что этические проблемы в социальной работе и связанные с ними стандарты постоянно развиваются. [2;сс.407-418]

Таким образом, внедрение искусственного интеллекта в социальную работу открывает значительные возможности для повышения точности диагностики нужд, персонализации помощи и оптимизации административных процессов. Вместе с тем успешное применение ИИ требует внимания к этике, защите данных и снижению алгоритмических предвзятостей, а также подготовки специалистов и участия сообществ в разработке решений. Чтобы обеспечить устойчивую пользу, необходимо сочетать технологические инструменты с человеческим фактором — экспертным суждением, эмпатией и профессиональной ответственностью.

Список литературы:

1.Лебедько, М. А., & Воротников, А. М. (2025). *Возможности и перспективы искусственного интеллекта в социальной сфере*. Журнал социологических исследований, № 3, сс.10–13.

2.Хассан, Б. (2022). *Искусственный интеллект в социальном обеспечении: возможности и вызовы*. The Journal of Social Policy Studies, 20(3), сс.407–418.

3. Бодрова, Е. В. (2021). Искусственный интеллект как инструмент развития социальной сферы. *Социальная политика и социология*, 20(2), сс.45–53.

4. Журавлёва, И. В. (2021). Этические риски использования искусственного интеллекта в социальной практике. *Журнал исследований социальной политики*, 19(3), сс.401–415.

5. Смирнова, О. В. (2020). Конфиденциальность персональных данных в условиях цифровизации социальных услуг. *Право и социальная защита*, № 5, сс.34–39.

6.Федоренко, Е. Г. (2021). Социальная работа в условиях цифровой трансформации общества. *Теория и практика социальной работы*, № 2, сс.5–11.

7. Назаров, М. М. (2023). *Искусственный интеллект и алгоритмические решения в социальной сфере: представления молодёжи*. *Социологическая наука и социальная практика*.

8. Цвык, В. А., & Цвык, И. В. (2022). *Социальные проблемы развития и применения искусственного интеллекта*. *Вестник Российского университета дружбы народов. Серия: Социология*, 22(1), сс.58–69.

9. Володенков С.В., Федорченко С.Н. Риски применения алгоритмов искусственного интеллекта в социально-политической сфере: обзор современных научных работ // Дискурс-Пи. – 2024. – № 2. – сс. 28–48.

10. Потапов М.П., Павлов А.В., Котловский М.Ю., Аккуратов Е.Г., Костров С.А. Искусственный интеллект в здравоохранении. / Учебное пособие. – Ярославль: Индиго, 2024. – 72 с

11. Петрова Т.Э. и др. Искусственный интеллект в социальной сфере. / Монография. – Москва: Издательство: КноРУС, 2025. – 176 с.

12. Котова Л.Б. Искусственный интеллект и качество социальных услуг // Наука, общество и образование в условиях трансформации социально-экономической сферы: Труды Всероссийской научно-практической конференции. Тверь, 2024. – сс. 490–496.

TECHNICAL SCIENCES

LONG RANGE FORECASTING OF RIVER FLOWS

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Abstract
A study focused on long range forecasting of river flows is presented. Two methods, artificial neural networks (ANNs) and multi linear regression (MLR) are employed for forecasting with time ranges changing between 1 day and 17 days. It was seen that the MSE values of ANN for the first 4 time ranges (1, 2 , 3 and 4 days) are lower compared with the corresponding MLR ones. For 5 days ahead and further forecasting the MSE values of MLR are lower than the ANN ones. The R^2 values for the time ranges 1, 2, 3, 4 and 5 days are equal for both methods. The MLR method has higher R^2 values for time ranges starting with 6 days.

Keywords: River flow; artificial neural networks; multilinear regression; long range forecasting.

Introduction

River flow forecasting is quite important for hydrology. In hydrological problems like flood modeling and dam spillway modeling river flow forecasting plays a significant role. In the literature the forecasting studies are based on one step ahead forecasting [1-15] . If the inputs of the forecasting model covers the time interval 't-1'-'t-n' the corresponding output time is 't'. For example if the time step is 'day' the available forecasting works are concentrated on 'one day ahead' forecasting. The long range forecasting, i.e. forecasting for output times 't+1',....,'t+n' is not examined in the literature. The long range forecasting can shed light to the future of the hydrological studies. If the researcher or engineer can have information for the future times the required precautions and adjustments on the hydrological works can be taken in advance. In the presented study different forecasting studies are employed for the long range forecasting of the selected river flow time series.

Data description

The daily mean flow data employed in the study is provided by the web site of United States Geological Survey (USGS). The measurement station name is Rio Grande at Otowi Bridge, NM. The station ID is 08313000. The basin area is 14300 sq.mi. The latitude and longitude of the station are 355229 and 1060830, respectively. The data record covers the time interval between 1955 and 1989. The training period for the forecasting is the first 80% of the whole record whereas the testing time period consists of the following 20% of the data. The basic statistics for the whole record, training record and testing record are presented in Table 1. The mean and standard deviation values of the testing period are higher compared with the training period (Table 1). The skewness of the training data is higher than the testing data (Table 1). The skewness values point to the positively skewed marginal probability distribution for the daily flow record. The first- and second-order autocorrelations are quite close to 1 pointing to the strong internal dependence of the data (Table 1).

Table 1. The description of the data statistics.

	Whole data	Training data	Testing data
Mean, x_m, (m^3/s)	39.18	34.54	57.75
Standard deviation, s_x, (m^3/s)	42.43	37.12	55.30
Skewness, c_{sx}	2.73	2.95	2.0
1st order autocorrelation, r_1	0.99	0.988	0.994
2nd order autocorrelation, r_2	0.978	0.974	0.985

The forecasting results

In the presented study two forecasting methods are used. The first one is an artificial neural network (ANN) method, the feed forward back propagation method (FFBP). The details of this method is available in the ANN literature [3-7]. The second method is a statistical method, i.e.the multi linear regression (MLR) method. For the ANN simulations the ANN toolbox of the MATLAB software is employed. The statistics toolbox of the EXCEL was used for the MLR computations. Two statistics are selected for the evaluation of the testing stage forecasting results, i.e. the mean square error (MSE) and the determination coefficient (R^2).

The input range of the ANN architecture constituted of 10 previous daily flows (times: t-10, t-9, t-8, t-7, t-6, t-5, t-4, t-3, t-2, t-1). The ANN had one hidden layer. The unique output of the ANN output layer corresponds to the future daily flow (time: t, t+1, t+2,....., or t+16). Similarly the MLR had 10 independent variables representing 10 previous daily flows and one dependent variable for the future time range. The MSE

and R^2 statistics for the testing data for 17 different future time ranges are presented in Table 2.

Table 2. Testing data forecasting statistics for ANN simulations and MLR for different time ranges.

Time range (days)	MSE (m^6/s^2) (ANN)	MSE (m^6/s^2) (MLR)	R^2 (ANN)	R^2 (MLR)
1	27	30	0.99	0.99
2	89	92	0.97	0.97
3	168	169	0.94	0.94
4	247	259	0.92	0.92
5	428	355	0.88	0.88
6	442	449	0.84	0.85
7	598	542	0.81	0.82
8	673	633	0.78	0.79
9	871	720	0.72	0.76
10	921	805	0.71	0.74
11	1082	885	0.66	0.71
12	1195	961	0.63	0.69
13	1338	1033	0.59	0.66
14	1311	1101	0.59	0.64
15	1377	1162	0.57	0.62
16	1465	1220	0.54	0.61
17	2198	1272	0.4	0.59

The MSE values of ANN for time ranges 1, 2 , 3 and 4 days are lower compared with the corresponding MLR ones (Table 2). Starting with the time range 5 (5 days ahead, t+4) the MSE values of MLR become lower than the ANN ones. The R^2 values for the time ranges 1, 2, 3, 4 and 5 days are equal for both methods. The deviation between R^2 values of two methods start from time range 6 on in the favour of MLR method. The lowest R2 values are obtained for time range 17 days (t+16) for the testing stage (R^2=0.40 for ANN, R^2=0.59 for MLR, Table 2). The variation of MSE and R^2 values with respect to different time ranges for both the ANN and MLR methods are shown in Figs. 1 and 2.

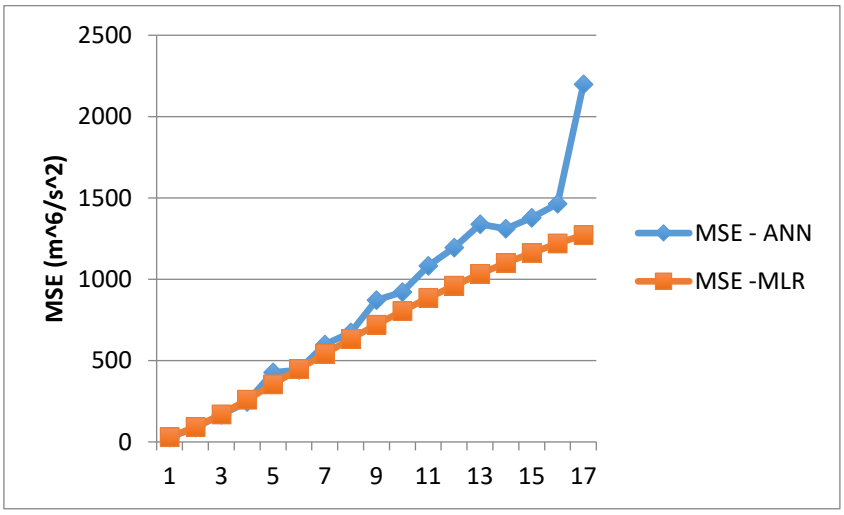

Fig.1. *The variation of MSE values with respect to time range (days) for ANN and MLR methods.*

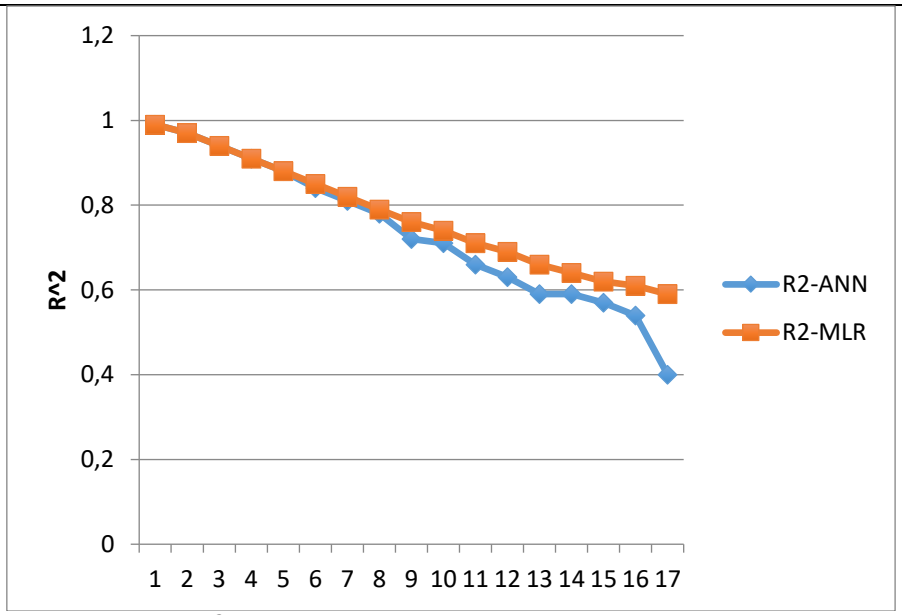

Fig. 2. *The variation of R^2 values with respect to time range (days) for ANN and MLR methods.*

The graphics for the scatter plots obtained with both methods for time ranges 1, 4 and 10 days (t, t+3 and t+9) are plotted in Figs. 3, 4, 5, 6, 7, 8.

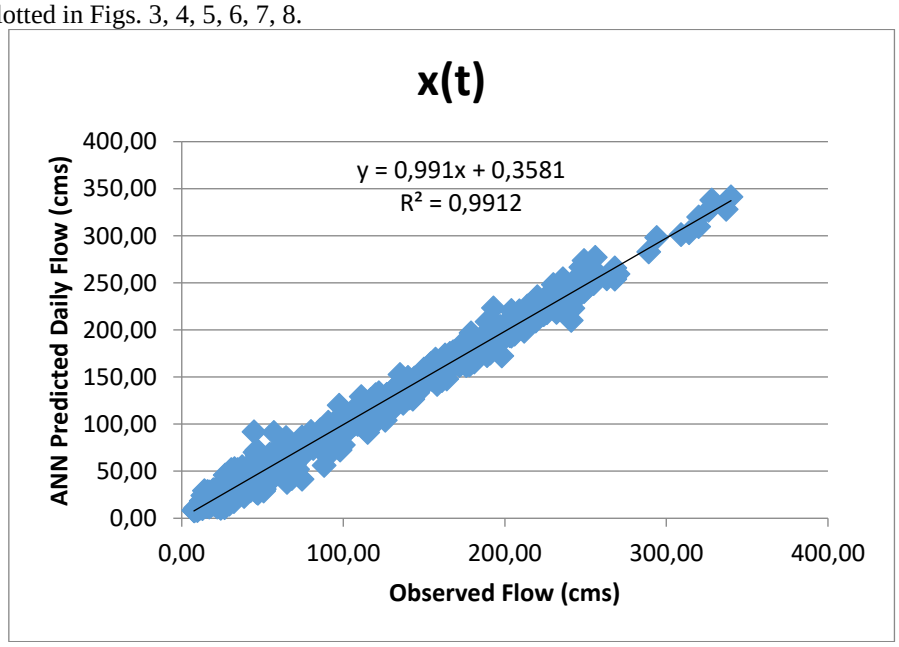

Fig.3. *The scatter plot for ANN predictions for time range 1 (1 day).*

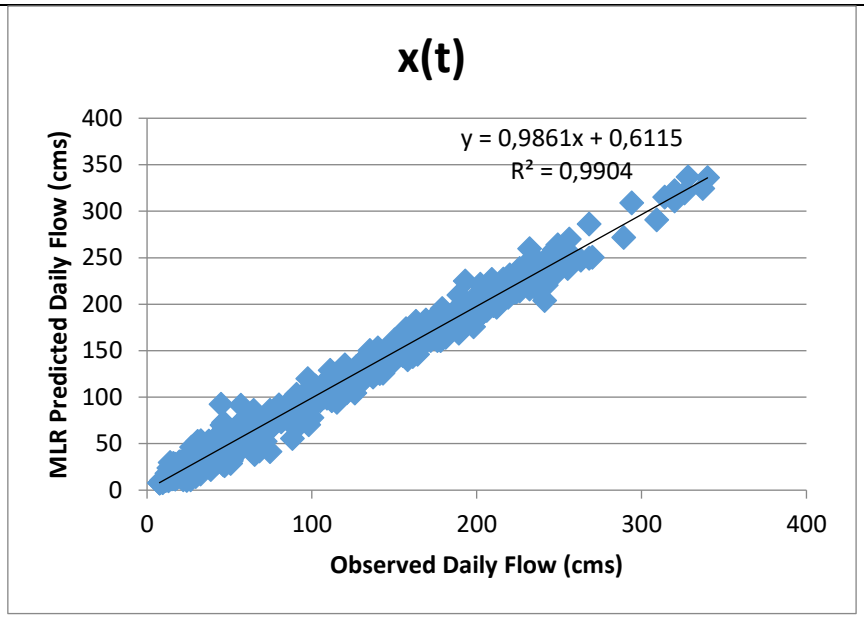

Fig.4. *The scatter plot for MLR predictions for time range 1 (1 day).*

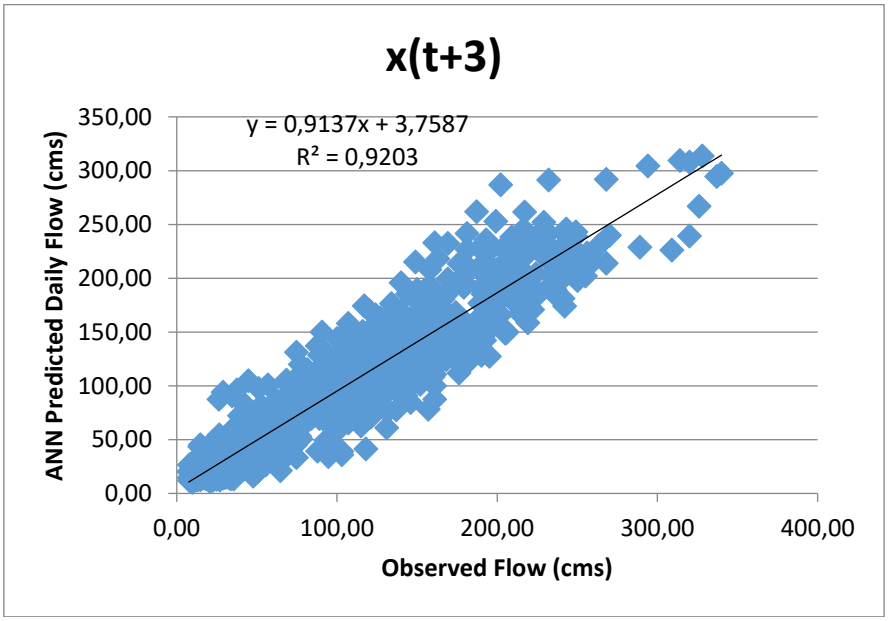

Fig.5. *The scatter plot for ANN predictions for time range 4 (4 days).*

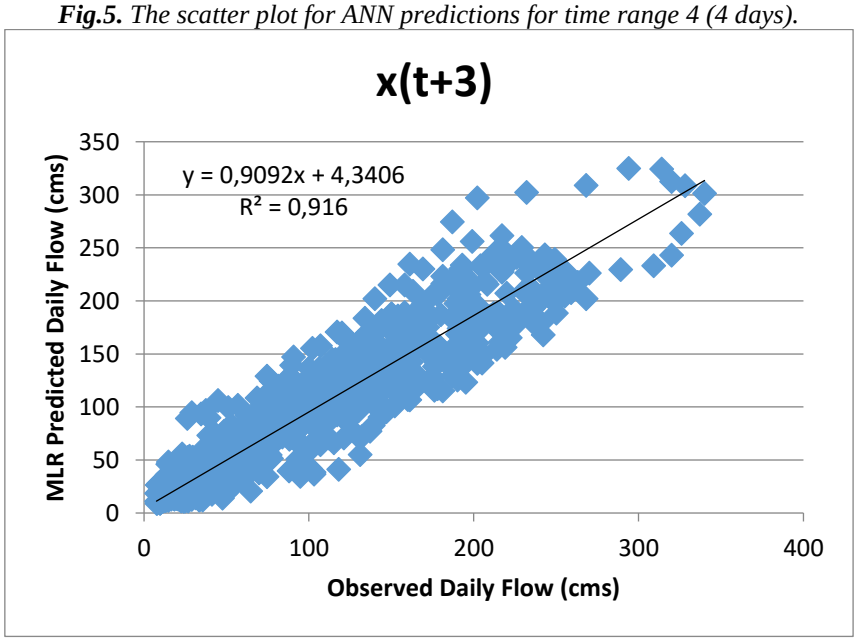

Fig.6. *The scatter plot for MLR predictions for time range 4 (4 days).*

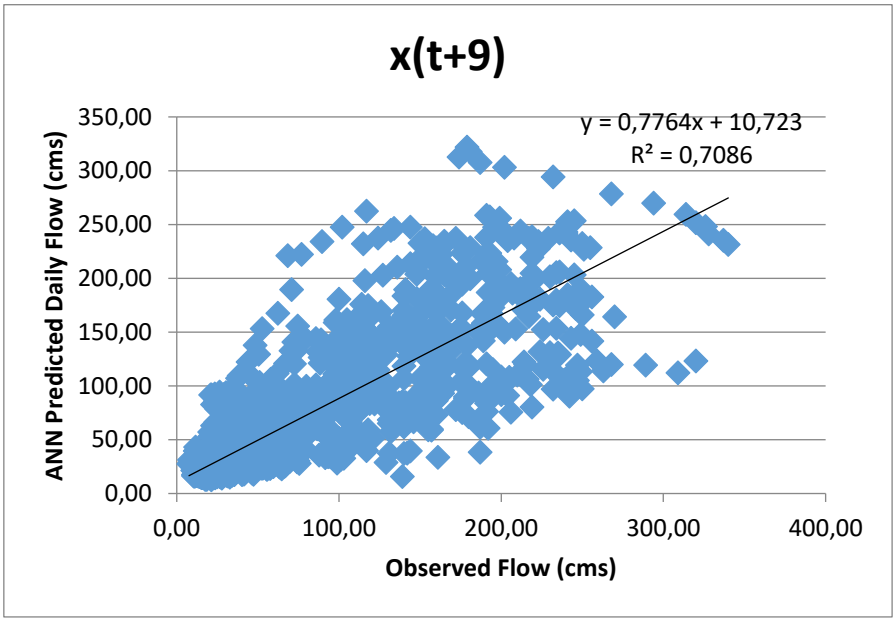

Fig.7. *The scatter plot for ANN predictions for time range 10 (10 days).*

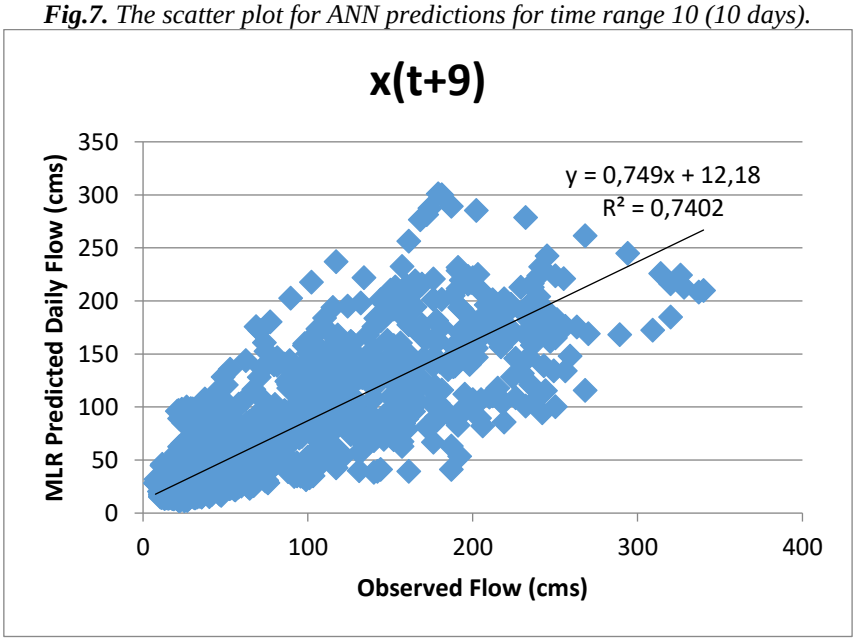

Fig.8. *The scatter plot for MLR predictions for time range 10 (10 days).*

In the case with time range 1 day the scattering is quite limited for both ANN and MLR methods with R^2 values nearly equal to 1 (Figs. 3 and 4). As time range increases to 4 days the scattering becomes obvious with R^2=0.92 for both methods (Figs. 5 and 6). The time range 10 days shows noticeable dispersion with slightly higher R^2 for MLR (Figs. 7 and 8).

Discussion and conclusion

The presented study examined the performance of two methods, i.e.ANN and MLR, for long range forecasting. The time range varied between 1 day and 17 days. It was seen that the MSE values of ANN for the first 4 time ranges (1, 2 , 3 and 4 days) are lower compared with the corresponding MLR ones. For 5 days ahead and further forecasting the MSE values of MLR are lower than the ANN ones. The R^2 values for the time ranges 1, 2, 3, 4 and 5 days are equal for both methods. The MLR method has higher R^2 values for time ranges starting with 6 days. The long range forecasting study can be considered as a beneficial tool in water resources studies like dam spillway management. As well known the dam spillway is one of the most significant parts of the dam structure. The performance of the spillway can be controlled if information is available for the future flows in the coming time intervals (days in the presented study). The potential damage on such a dam structure due to an excessive increase on the entering flow can be prevented or decreased with an effective forecasting strategy.

References:

1. Alp, M., Cigizoglu, H.K. (2007).“Suspended sediment estimation by feed forward back propagation method using hydro meteorological data”, Environmental Modelling & Software, 22(1), 2-13.

2. ASCE. (2000). “Task committee on applicaton of artificial neural networks in hydrology: Artificial neural networks in hydrology. Part II—Hydrologic applications.” J. Hydr. Eng., 10.1061/(ASCE)1084-0699 (2000)5:2(124), 124–137.

3. Cigizoglu, H.K. (2003). ”Estimation, forecasting and extrapolation of river flows by artificial neural networks.”, Hydrological Sciences Journal, 48(3), 349-361.

4. Cigizoglu, H.K.(2003).”Incorporation of ARMA models into flow forecasting by artificial neural networks.”, Environmetrics, 14, 4, 417-427.

5. Cigizoglu, H.K.(2004).”Estimation and forecasting of daily suspended sediment data by multi layer perceptrons.”Advances in Water Resources, 27, 185-195.

6. Cigizoglu, H.K. (2005).“Application of the Generalized Regression Neural Networks to Intermittent Flow Forecasting and Estimation”, J. Hydr.Eng., 10(4), 336-341.

7. Cigizoglu, H.K.(2005). “Generalized Regression Neural Network in Monthly Flow Forecasting”, Civil Engineering and Environmental Systems, 22 (2), 71-84.

8. Cigizoglu, H.K., Alp, M. (2006).“Generalized Regression Neural Network in modelling river sediment yield.”, Advances in Engineering Software, 37(2), 63-68.

9. Kişi, Ö. (2004).“River flow modeling using artificial neural networks.” J. Hydr. Eng., 10.1061/(ASCE)1084-0699(2004)9:1(60),60–63.

10. Kişi, Ö. (2007).“Streamflow forecasting using different artificial neural network algorithms.” J. Hydrol. Eng.,10.1061/(ASCE)1084-0699 (2007)12:5(532), 532–539.

11. Linares-Rodriguez, A., Lara-Fanego, V., David Pozo-Vazquez, D., Tovar-Pescador, J. (2015).” One-day-ahead streamflow forecasting using artificial neural networks and a meteorological mesoscale model.” J. Hydr.Eng., 20(9): 05015001.

12. Sertel, E., Cigizoglu, H.K., Sanli, D. U. (2008).“Estimating daily mean sea level heights using artificial neural networks.”, Journal of Coastal Research, 24(3), 727–734.

13. Tayfur, G. (2012). Soft computing in water resources engineering: Artificial neural networks, fuzzy logic and genetic algorithms, WIT Press, Southampton, U.K.

14. Ustaoglu, B., Cigizoglu, H.K., Karaca, M.(2008).”Forecast of daily mean, maximum and minimum temperature time series by three artificial neural network methods.”, Meteorological Applications, 15 (4), 431-445.

15. Wu, J., Han, J., Annambhotla, S., and Bryant, S. (2005). “Artificial neural networks for forecasting watershed runoff and stream flows.” J. Hydr.Eng., 10.1061/(ASCE)1084-0699(2005)10:3(216), 216–222.

STEADILY DISCHARGING ECCENTRIC WELLS: COMPARING NUMERICAL SIMULATIONS TO EXISTING EXPERIMENTS

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Abstract

Operation of eccentric wells in a circular island unconfined aquifer under steady state flow conditions was addressed in this study by comparing the results of experimental, analytical and developed numerical models. MODFLOW was used in the developed numerical models. The results include simulations of various refined meshes. Such relationships are of practical importance in operating eccentric wells in unconfined radial flow systems. The objectives of this study were: 1) to determine the drawdown ranges, in terms of their agreement, among the numerical, experimental, and analytical solutions; 2) to test whether the MODFLOW (using PCG2 and PCGN solvers) provides accurate results for such wells; and 3) to investigate the sensitivity of the numerical solutions to mesh size and eccentricity. The results showed that all solutions performed better for smaller drawdowns in eccentric wells than they do for larger drawdowns; and for smaller drawdowns, analytical and PCG2 models provided good agreement taking into consideration root-mean-square error as evaluation criteria. For larger drawdowns, analytical and PCG2 either grossly overestimated the drawdown values or became inapplicable as the hydraulic head in well dropped to zero. PCGN solver performed best for both smaller and larger drawdowns, but the parameter selection needs care. Eccentricity and mesh size have effects on the solutions, especially for parameter estimation in PCGN, and the consistency of outputs requires investigation of optimal mesh size depending on eccentricity. When compared to wells with larger eccentricity, linear PCGN (PCGN1) performed better for large eccentricity regardless of mesh size, while PCG2 performed better for wells closer to the concentric. Numerical methods predicted larger drawdowns for finer mesh spacing size. Based on these results, numerical solutions could be used to adequately describe the drawdown for a well placed eccentrically within a circular island unconfined aquifer under steady state flow conditions provided the modeling parameters are dealt with scrutiny.

Keywords: Drawdown, Eccentric well, Unconfined circular aquifer, Numerical model

Introduction

Hantush and Jacob (1960) conducted a theoretical study under steady state flow conditions for a discharging well located eccentrically in a circular confined aquifer along whose outer cylindrical boundary either the drawdown or the flux is zero. De Wiest (1963) performed an analytical solution for the flow to an eccentric well in a leaky circular aquifer with lateral replenishment, for both steady and unsteady flow conditions. Later on, Verruijt (1982) developed a theoretical equation for the wells eccentrically located in an unconfined circular aquifer under steady state flow conditions. Birpinar and Gazioglu (2002) performed an experimental study for wells located eccentrically in an unconfined aquifer with finite extent to test the validity of the equation presented by Verruijt (1982); they concluded that the Verruijt (1982) equation is valid for small drawdowns. According to Mishra and Kuhlman (2013), despite the many advanced solution methods available, there exists still a need for realism to simulate real-world aquifer tests accurately.

In this study, Processing MODFLOW (which uses structured rectilinear grids mesh) was adopted to simulate the wells eccentrically located in a circular island unconfined aquifer. For MODFLOW solutions and, the sensitivity of the solution to mesh size and eccentricity was investigated by changing the regional and local grids. A comparison was performed with the experimental results of Birpinar and Gazioglu (2002) and the analytical solution of Verruijt (1982). A priorly developed FORTRAN Code (FC) by the last author that uses finite difference method was also adopted for comparison purposes.

The objectives of this study were to determine the drawdown ranges where the mentioned solution methods approximate the experimental and/or each other; to investigate the sensitivity of the numerical solutions to mesh size; and to test whether the MODFLOW (using PCG2 and PCGN solvers) provided accurate results for wells eccentrically located in unconfined circular aquifer under steady state flow conditions. Based on the comparison of these solution methods, the drawdown and the discharge-drawdown relationship at the well in operation under different discharge rates were predicted. Understanding such relationships is of practical interest in operating unconfined radial flow systems. It was assumed that the aquifer is homogeneous, the wells are unlined and fully penetrated the aquifer thickness, Darcy's law is valid for the flow in the aquifer, and only one well is pumped at a time using a constant discharge rate until equilibrium conditions occur.

Model of the study

To have a direct, logical and easy comparison between the results of the available experimental and analytical solutions with MODFLOW, the considered flow domain was discretized in a way that the wells are placed at locations within the aquifer as those in Birpinar and Gazioglu (2002) experiments (Fig. 1). The performances of all models were compared for the same soil properties, problem dimensions and flow geometry. The physical experimental study was constructed using a sand model contained in a square box. The thickness of the circular aquifer model was 50 cm. The boundary condition head in the sand model was kept constant at about 7 cm below the sand surface. In brief, the constant values for the applied circular aquifer model were taken as: H = 42.8 cm (referred to the base of the aquifer), k = 0.468 cm/s, r_w =1.75 cm and r = 96 cm, where H is the height of initial water table, k is the permeability of the unconfined aquifer, r_w is the well radius, and r is the radius of the aquifer (radial distance from the center of the aquifer to its external circular boundary).

Analytical solution

Using the image well theory, Verruijt (1982) developed an analytical equation for a sink ($+Q$) placed eccentrically at $x = p$, $y = 0$ as shown in Fig. 2, where p is the well eccentricity. The problem was solved by inserting a source ($-Q$) at $x = r^2 / p$, $y = 0$, where both sink and source were operating in an infinite circular unconfined aquifer. With application of appropriate boundary condition, Verruijt obtained that:

$$h_w^2 - H^2 = \frac{Q}{\pi k} \ln\left(\frac{r_w r}{r^2 - p^2}\right) \quad (1)$$

When the eccentricity $p = 0$, Eq. (1) reduces to Dupuit's expression derived by integrating Darcy's law for steady flow around a well in a homogeneous and isotropic unconfined aquifer.

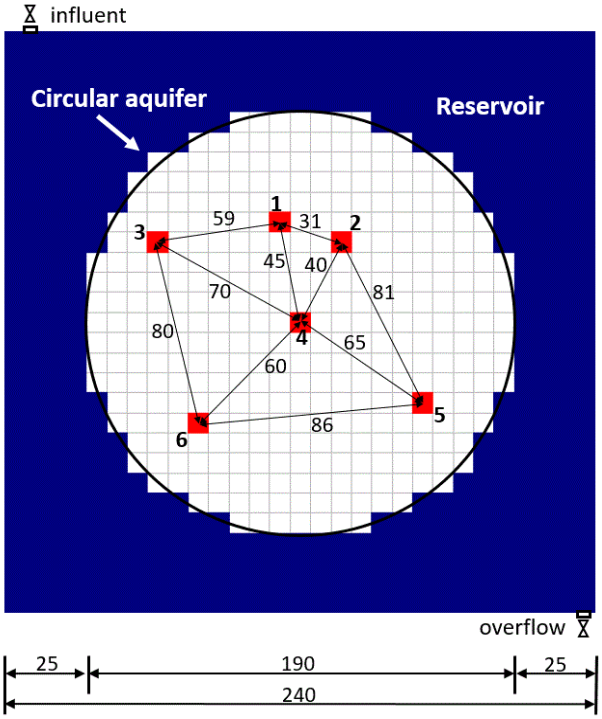


Fig. 1 Well locations in a 29x29 global grid system, units in cm. Red squares represent the wells with their numbers.

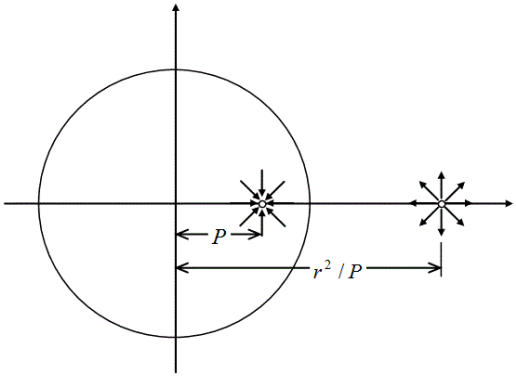


Fig. 2 Schematic sketch with sink and source for Verruijt analytical solution

Governing equation & boundary conditions

With MODFLOW-2005, using block centered flow package, unconfined layer property and well package under MODFLOW model, the problem at hand was solved using PCG2 and PCGN solvers. Some results were compared to finite difference method results conducted using Fortran Code (FC) prior to this work. The code solved Eq.(2) using Gauss-Seidel iteration with successive over-relaxation. The equation provides the two-dimensional model for incompressible steady groundwater flow in a homogeneous unconfined aquifer and was formulated introducing Dupuit's assumption that head, h, does not vary in the vertical direction (i.e., $\partial h/\partial z = 0$) resulting in horizontal flow (Wang and Anderson, 1982).

$$\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} = -\frac{2R(x,y)}{k} \qquad (2)$$

where $v = h^2$, $R(x,y)$ is the volume of water recharged per unit time per unit aquifer area and $R(x,y) = Q/\Delta x \Delta y$, where Q is the discharge rate from the well and k is the hydraulic conductivity. Those results are used to make partial comparison to MODFLOW results.

Dirichlet boundary condition was considered in this study for MODFLOW (and FC). That is, the head is known (h = constant = 42.8 cm) for all the nodal points on the outer circular boundary of the flow region and remains unaffected for distances greater than the radius of the aquifer. In FC, the solution of these equations were first obtained in terms of (v) and the head (h) at all nodal points were then obtained by taking into consideration the square root of v. Previous researches by Boulton (1951), Hantush (1964), and others proved by mathematical procedures that the discharge obtained by introducing the Dupuit assumption represents a correct solution even though the water table obtained by the same procedure, known as Dupuit parabola, significantly deviates from the real water table, especially where the streamlines are strongly curved. According to Clement et al. (1996), the deviation from Dupuit discharge is within 1 to 2 %. Shamsi and Narasimhan (1991) suggested that the Dupuit model underestimates the discharge because the flux through the seepage face is ignored and the deviation may range up to 10 to 12 %. Siddiraju (2013) concluded that the specific capacity of open wells increases as the diameter of the well increases.

MODFLOW

Well locations (eccentricity), discharge rates, and domain mesh (both regional and local) are the varying concepts in both the FC and MODFLOW models. The Pickard iteration number, however, is only introduced to MODFLOW models. Simulations were done using various uniform grids to which, later, local refinement was also applied. Preconditioned Conjugate-Gradient solvers PCG2 and PCGN (MODFLOW-2005) with parameters in Table 1 were used to solve the matrices. All parameters were kept constant except one of the three outer iteration number (*iter_mo*) in PCGN. The linear solution was obtained using *iter_mo* 1, and the converged result was obtained by picking a high number—100. An extra step was then considered to test the possibility of obtaining a meaningful output by restricting the iteration number.

Table 1 Parameters used A) in PCG2 solver and B) in PCGN in MODFLOW

A) PCG2

Preconditioning method	**Allowed Iteration #**		**Convergence Criteria**		**Damping**
	Relaxation Parameter	Outer Iteration	Inner Iteration	Head Change (cm)	Residual (cm^3/s)	Damping Parameter
MIC	.99	50	30	.001	.001	1

B) PCGN

Preconditioning method	**General Solver Parameters**				**Damping**	**Convergence of Inner Iteration**
	Relaxation Parameter	Outer Iteration	Inner Iteration	Residual CLOSE_R	Head Change (CLOSE_H)	Damping Parameter	ACNVG
MIC	.99 | 0 fill	1|TBD| 100	500	.001	.001	ADAMP: 0 DAMP: .5	0

To decide the optimal *iter_mo* with the model at hand (beside 1 and 100), its effects on discharge and on well location were analyzed (Fig. 3). Discharge magnitude had almost no effect on *iter_mo* (Fig. 3a); thus, a single *iter_mo* can be chosen for a well pumped with various discharges (e.g. nine is representative enough for well 4). Our analyses showed that well location does require increasing *iter_mo*s as the distance from the constant head boundary becomes larger (Fig. 3b). There is an optimal *iter_mo* below and above which the solutions are not as close to the experimental study. This, however, is only a problem faced with larger discharge rates. With lower discharge rates, the simulations provide robust outputs. For identifying *iter_mo*s

in PCGN solver, if no observation data is available, the following procedure may be applied: analytical and numerical solutions already provide comparable results for the center well, from which one can identify the ideal *iter_mo* for the model by adjusting *iter_mo*s. For a trend to be obtained, a second *iter_mo* at another location is needed, which could be the one at the outer boundary where the *iter_mo* functions close to unity. The only exception to increasing *iter_mo* concept is well 5; its results mimic that of well 1. It should be noted that the experimental model gives completely different discharge-drawdown relationships than any of the analytical equation or the developed numerical models for well 5. Its relation should be between those of wells number 6 and 3, but it does not. Birpinar and Gazioglu (2002) repeated their experimental work, but the result of well 5 did not change. This is not the case with any of the analytical or the numerical results, which give correct behaviors as expected for all wells when their eccentricity is considered. The pronounced deviations in the experimental results and the different behavior of well 5 may suggest that the experimental model requires sensitivity analysis to changes in the well radius and model size. Its closeness to the overflow or remoteness to the inflow in the sand tank could be another explanation to this.

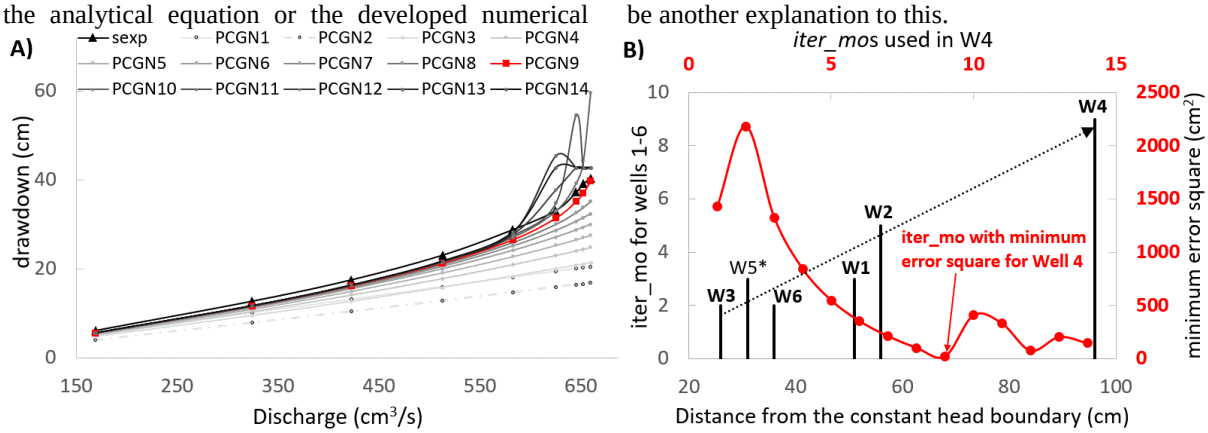
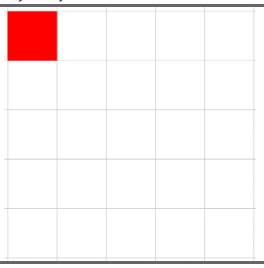
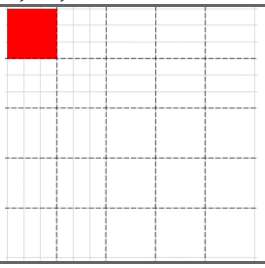
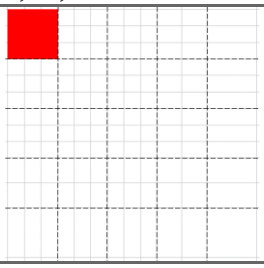


Fig. 3 *Deciding optimal iter_mo: a) results obtained using different iter_mos for all discharge rates applied to well 4 (experimental drawdowns in black triangles and best match in red squares); and b) the optimal iter_mos.*

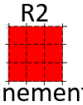
Four different uniform global grids were applied to the study area for MODFLOW and FC (Table 2), finest approximately having the area of wells constructed in the experimental model. For MODFLOW only, each global system was refined at and around the wells (Table 2).

Table 2 A) Four different global meshes, showing the number of layers, rows, and columns before and after refinement; B) visualization of (A) in close proximity to the well in operation, extracted from MODFLOW.

A)	**Layers, Rows, Columns**		
Discretization	**Pre-refinement (FC & MODFLOW)**	**Refinement I (MODFLOW Only)**	**Refinement II (MODFLOW Only)**
Case I	1, 25, 25	1, 31, 31	1, 37, 37
Case II	1, 29, 29	1, 35, 35	1, 41, 41
Case III	1, 51, 51	1, 57, 57	1, 63, 63
Case IV	1, 77, 77	1, 83, 83	1, 89, 89
B) Changes with refinement in well cell(s) (in red) and the first four neighboring cells in the lower right-hand portion of wells			

Referred to as *refinement I* and applied to each well position in all global systems, the eight cells enclosing the well in global grid system was refined by inserting two rows and two columns, thereby splitting each mentioned global cell into nine cells (Table 2). To avoid the refinement of one well affecting the mesh of other wells, *Refinement I* was implemented in different MODFLOW models for each well. In *refinement II*, applied only to Well 1 in all four global grids, variable spacing employed. In *refinement I*, only the first neighboring cells were used enclosing the well; in *refinement II*, second and third neighboring cells were also added to the first. Adding two columns and two rows applied to the first and second neighboring cells, and only one column or one row was added to the third—thus the name variable.

Table 3 A rough flow chart with the corresponding model names in MODFLOW. n varies with each well.

DEFINITION / FLOW	**MODEL NAME**		
	Refinement at the well	**Solver**	***Iter_mo***
• Form a uniform grid in MODFLOW • Pick a well and locate its position • Run simulations for all experimental discharge rates	 non-refined	PCGN ↑ Solver	1 | n | 100 ↑ Iter_mo
• Apply refinement I and • average the drawdowns of nine small wells • Run simulations for all experimental discharge rates	R Refinement I	PCGN ↑ Solver	1 | n | 100 ↑ Iter_mo
• Use single refined center cell (only applied to well 1) • Run simulations for all experimental discharge rates	SCWR Refinement I	PCGN ↑ Solver	1 | n | 100 ↑ Iter_mo
• Apply refinement II (only applied to well 1) • average the drawdowns of nine small wells • Run simulations for all experimental discharge rates	R2  Refinement II	PCGN ↑ Solver	1 | n | 100 ↑ Iter_mo

In all local refinements, there was peripheral refinement in that the rows and columns added extend throughout the model domain. Therefore, while it would be expected, for example, the third neighboring cells divided into two, in MODFLOW, they are divided into six cells due to the refinement of closer neighboring cells to the well-corner cells split into four with intersection of third neighboring cells' refining column and row. Because of this, the well itself too, in all refined models, were divided into nine cells (Table 3). The focus in local refinement was on obtaining detailed information about large hydraulic gradients and on getting results that represents the reality (i.e. experimental results) better. The well area was kept as in the global grid, and the pumping rates were scaled by the cell area, dividing the discharge by 9. The sum of the pumping rates (and the area) remain the same as that of the global single-cell well. Only for Well 1 was the well area changed by a factor of nine, using a single-cell after applying *refinement I* (SCWR in Table 3).

Analyses of the results

The experimental and the analytical drawdowns were drawn in Fig. 4. Analytical model considerably overestimates the drawdowns for all wells except Well 4.

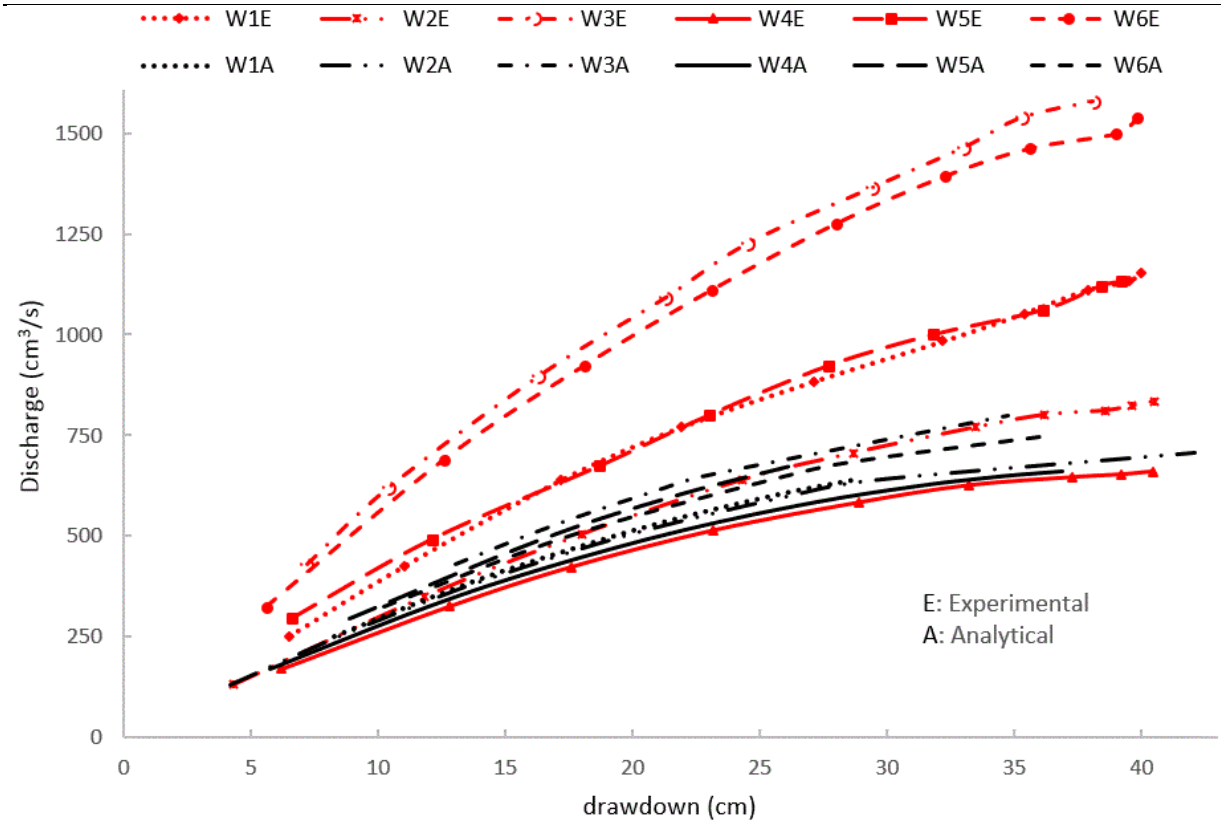


Fig. 4 Discharge-drawdown relationship from experimental and analytical models for wells 1 to 6

Table 4 shows the percentage differences in Well 1 for *case I* discretization (similar calculations and discharge-drawdown relationships were obtained for all wells). The differences between the experimental and analytical, and experimental and numerical results were considerable and mostly increase as the discharge rates increase. Consistent decrease takes place for PCGN1 and SCW RPCGN1; however, it is only for PCGN1 that the decrease is meaningful with a range from 11.4% to 1.6%. PCGN3's percentage difference, on the other hand, differs in that, first an increase and then a decrease takes place, which is promising for the accuracy of larger discharge rates. Difference for SCW models results are almost double. Interestingly, for 769.2 cm^3/s, models with *refinement I* and *refinement II* seem to plateau with an average difference of 17.9%. For FC, the difference increases as the discharge rate increases. Because PCG2 results replicated the results of PCGN100, they were omitted from the study altogether. Similarly, analytical, FC, and PCGN100 results almost overlap, producing similar errors when compared with the experimental model.

Table 4 Smaller drawdown values of well 1, corresponding to the smallest 4 of 10 discharge rates applied in the experimental model. For model names, refer to Table 1; NA symbolizes that the model does not provide any drawdown because the head reaches the bottom of the well with a lower discharge rate. For numerical solutions, case I mesh is applied.

Q (cm^3/s)	**250.2**	**425.4**	**638.4**	**769.2**
Experimental drawdown, s (cm)	6.5	11.05	17.2	21.9
Analytical drawdown, s0 (cm)	8.3	15.5	28.7	NA
Error % between s & s0	27.2	40.4	66.6	
FC drawdown, s1 (cm)	8.0	14.9	27.0	NA
Error % between s & s1	22.8	34.9	56.8	
PCGN1 drawdown, s2 (cm)	7.2	12.3	18.5	22.3
Error % between s & s2	11.4	11.4	7.4	1.6
PCGN3 drawdown, s3 (cm)	6.7	11.8	18.9	23.7
Error % between s & s3	2.6	7.1	9.6	8.4
PCGN100 drawdown, s4 (cm)	8.0	15.0	NA	NA
Error % between s & s4	23.0	35.93		
RPCGN1 drawdown, s5 (cm)	5.9	10.0	15.0	18.0
Error % between s & s5	9.7	9.7	12.9	17.6
RPCGN3 drawdown, s6 (cm)	5.3	9.4	14.7	18.2
Error % between s & s6	17.8	15.2	14.7	16.9
RPCGN100 drawdown, s7 (cm)	6.3	11.5	19.4	26.1
Error % between s & s7	2.5	4.3	12.6	19.2
R2PCGN1 drawdown, s8 (cm)	5.8	9.9	14.9	17.9
Error % between s & s8	10.3	10.3	13.6	18.2
R2PCGN3 drawdown, s9 (cm)	5.3	9.3	14.6	18.1
Error % between s & s9	18.4	15.8	15.3	17.4
R2PCGN100 drawdown, s10 (cm)	6.3	11.4	19.2	25.8
Error % between s & s10	3.2	3.5	11.6	18.0
SCW RPCGN1 drawdown, s11 (cm)	9.5	16.1	24.2	29.1
Error % between s & s11	45.7	45.7	40.5	32.9
SCW RPCGN3 drawdown, s12 (cm)	8.9	16.0	26.2	34.0
Error % between s & s12	36.3	44.4	52.3	55.3
SCW RPCGN100 drawdown, s13 (cm)	10.9	21.9	NA	NA
Error % between s & s13	67.1	97.7		

Root mean-square errors ($RMSE$) were calculated for each well using drawdown differences between Birpinar and Gazioglu (2002) measurements and those obtained from the developed numerical models for all four grid cases (Table 5). In order also to consider the effect of discharge rate magnitude, first, the smallest two discharge rates and their corresponding drawdowns were combined ($RMSE_1 = \sqrt{\frac{\sum_{i=1}^{2}(s_{ip} - s_{ia})^2}{2}}$, where s_{ip} and s_{ia} are the calculated and the experimental drawdowns, respectively). Second, all discharge rates, large and small, for which the drawdowns obtained were used (i.e. the well does not become dry applying that discharge rate on the numerical solution; $RMSE_2 = \sqrt{\frac{\sum_{i=1}^{n}(s_{ip} - s_{ia})^2}{n}}$). Some methods produce results for high discharge rates for the same well (and grid) while others do not; results were also affected by the global grid and local refinements. For example, for 29x29 grid (*case II)*, well 2 operates for a

maximum discharge of 504 cm^3/s for PCGN100 model, while the same well runs for the 833.4 cm^3/s and still provides a hydraulic head of 17.3 cm for PCGN1 method. For 77x77 grid (*case IV)*, well 2 becomes dry before reaching a discharge of 504 cm^3/s—if refinement is applied, discharge rates go up to 769.2 cm^3/s for PCGN100 (i.e. RPCGN100) and the well still does not become dry.

Table 5 *RMSE* obtained using drawdowns from numerical and experimental models for all four grid cases. For each column, the first value is for the small drawdown (maximum drawdown of 11.8 cm, using first two discharges applied to the well.

		FC (cm)		**MODFLOW (cm)**											
				PCGN1		PCGNn		PCGN100		RPCGN1		RPCGNn		RPCGN100	
Case I	W1	2.9	6.1	1.0	4.1	0.6	1.7	3.0	3.0	0.9	8.8	1.4	6.8	0.4	3.5
	W2	0	3.9	1	10.3	0	0	0	1	2.4	13.9	2.2	9.8	1.7	8.6
	W3	8.2	8.2	4.6	5	1.7	1.7	8.8	8.8	1.7	3.3	0	6.2	3.6	6
	W4	1	3.7	2	12.6	1	1.7	1	1	3.5	15.4	2.6	11.3	2.6	11
	W5	2.8	7.1	1	5.9	0	2.6	3	6.2	1.4	10.4	2	9.7	0	5.6
	W6	11.1	11.1	4.9	5.3	2	2.2	4.3	4.3	2	3.6	0	6.3	5	9.7
Case II	W1	3.5	7.3	1.4	3.5	1	2.6	3.6	3.6	0	7.7	1	5.4	1	3
	W2	0	3	1	9.8	0	0	0	1.5	2.2	13.3	2	8.8	1.4	7.3
	W3	8.7	9.3	4.8	5.5	2	2.2	9.3	9.3	1.7	3	0	5.7	3.9	6.9
	W4	0	2	1.7	12.2	0	1	0	0	3.2	15.1	2.4	10.6	2.4	10.3
	W5	3.3	10.1	1.4	4.7	1	1	3.9	3.9	1	9.2	1.4	8.1	0	4.5
	W6	14.4	14.4	5.2	5.8	2.2	2.8	4.6	4.6	2.2	3.3	0	5.7	5.5	26.7
Case III	W1	6	6	3.0	2.8	2.6	6.4	6.2	6.2	1	4	0	1	3	6.7
	W2	2.2	4.5	0.4	6.9	1.4	6.2	2.2	5.2	1	10.3	0.5	2.6	0.2	4.5
	W3	14.1	14.1	7.3	10.8	4.1	7.4	9.1	9.1	4.4	4.7	1.6	1.5	8	9.4
	W4	1	5.8	0	9.8	1	2.8	**4.7**	**4.2**	2	12.6	1	5.1	1	6.9
	W5	6.6	14.1	3.2	2.6	2.8	5.1	6.9	6.9	1	5.7	0	3	3	5
	W6	6.7*	6.7	7.8	11.2	4.6	7.9	6.7*	6.7	4.9	5.2	2	2	11.3	11.6
Case IV	W1	8.1	8.1	4.2	5.5	3.9	9.6	8.3	8.3	2.2	2.2	1.7	4.6	4.8	7.5
	W2	3.5	7.2	1.2	3.7	2.4	7.5	3.6	3.6	0.2	8.2	0.6	3.2	1.3	3.1
	W3	20	20	9.1	13.3	5.6	9.9	11.5*	11.5	6.2	8.4	3.1	4.8	11.4	13.2
	W4	2.3	6.2	0.4	8.2	2.2	6.2	2.4	4	1.2	11	0.2	1	0.3	5.8
	W5	9.2	9.2	**4.5**	**3.7**	4.2	7.9	9.8	9.8	2.2	3.3	1.8	2	5.1	6.3
	W6	8.2	8.2	9.6	13.2	6.2	9.6	8.3	8.3	6.6	9.3	3.5	5.5	12.2	12.2

Aiming to decide which method provides better results and with which grids, we observed another parameter taking a role in conclusions: the eccentricity-distance of the well to the concentric well. Because of this, while comparing the methods; we looked into the effect of well location with respect to the distance from the center of the circular aquifer. The FC performs best for the center well and the wells closer to it when compared to the wells a far from the aquifer center; so does the analytical solution. As the wells get farther from the center and closer to the specified boundary, the FC results diverge further from the experimentals for a single operating well. *Case II* grid is optimal for the center well, and closest to it, well 2; as the distance from the center increases, finer global grids (*case III*) work better, but for wells too close to the boundary, none is appropriate that there may be an optimal grid somewhere between 29x29 and 51x51 (Table 5; refer to Fig. 1 or 3b for eccentricity).

PCGN1, the linear solution, provides good results overall for wells 1 and 5, regardless of grid size. PCGN100, which is the converged case without local refinement, produces better results regardless of the global grid when the wells located within the inner part of the aquifer diameter, and as far as *RMSE* s are concerned, *case I* provides better approximations. Nonetheless, for PCGN100, MODFLOW provides outputs only for the smaller discharges used in Birpinar and Gazioglu (2002) study, meaning PCGN100 grossly overestimates the drawdowns (except for well 4 in coarser

grids), so the number of outputs included for the wells is fewer comparing with other methods used in MODFLOW.

PCGNn functions well in general, but coarser grids provide even better results; maximum *RMSE* for *case I* is 2.6 cm (Fig. 5a). For finer global grids, the results using mentioned *iter_mos* do not show any success unless local refinement is applied. RPCGNn, which is the latter mentioned case, produces overall the best predictions for finer global grids; Wells 1, 2, 3, and 6 are better with *case III*, 4 and 5 with *case IV* (Fig. 5B). Considering Well 5, which has high systematic errors in the experimental model, it could be stated that, for eccentric wells, *case III* is the optimal grid among the ones tested in this study using RPCGNn (Table 5; Fig. 5b).

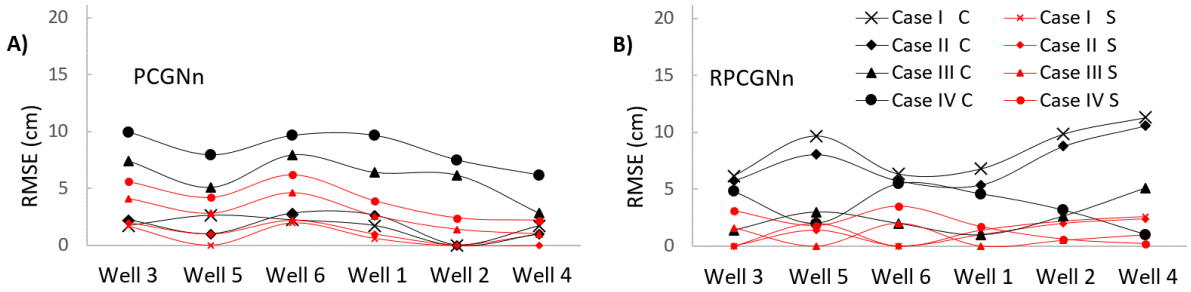


Fig. 5 *Grid effect on a) PCGNn and b) RPCGNn models with respect to well location, for all drawdowns. C stands for cumulative and S for small, indicating the range of drawdowns included in RMSE calculations*

RPCGN1 always produces unfavorable results for Wells 2 and 4 (at and the closest to the center), regardless of the global grid used. With coarser global grids, Wells 3 and 6 (wells closest to the constant head boundary) outputs acceptable results; when 51x51 is used, Wells 3, 5, 6, and 1 (closest to the boundary) provides better results; and with 77x77, 5 and 1 generate better. With RPCGN100, Well 6 produces higher *RMSE*s with all global grids while Well 5 provides somehow acceptable close-results for all grids (Table 5).

For small discharge rates, the *RMSE*s are mostly considerably small, except the bolded ones in Table 5 (only two exceptions to this took place with finer grids (*cases III* and *IV*) for PCGN100 and PCGN1 models, in Wells 4 and 5, respectively). Cumulative *RMSE*s for PCGN1 and RPCGN1 are highly larger than that of smallest two drawdowns. For PCGNn, *cases III* and *IV* produce large differences, while for RPCGNn and RPCGN100 in *cases I* and *II* the results largely differ according to the discharge rate.

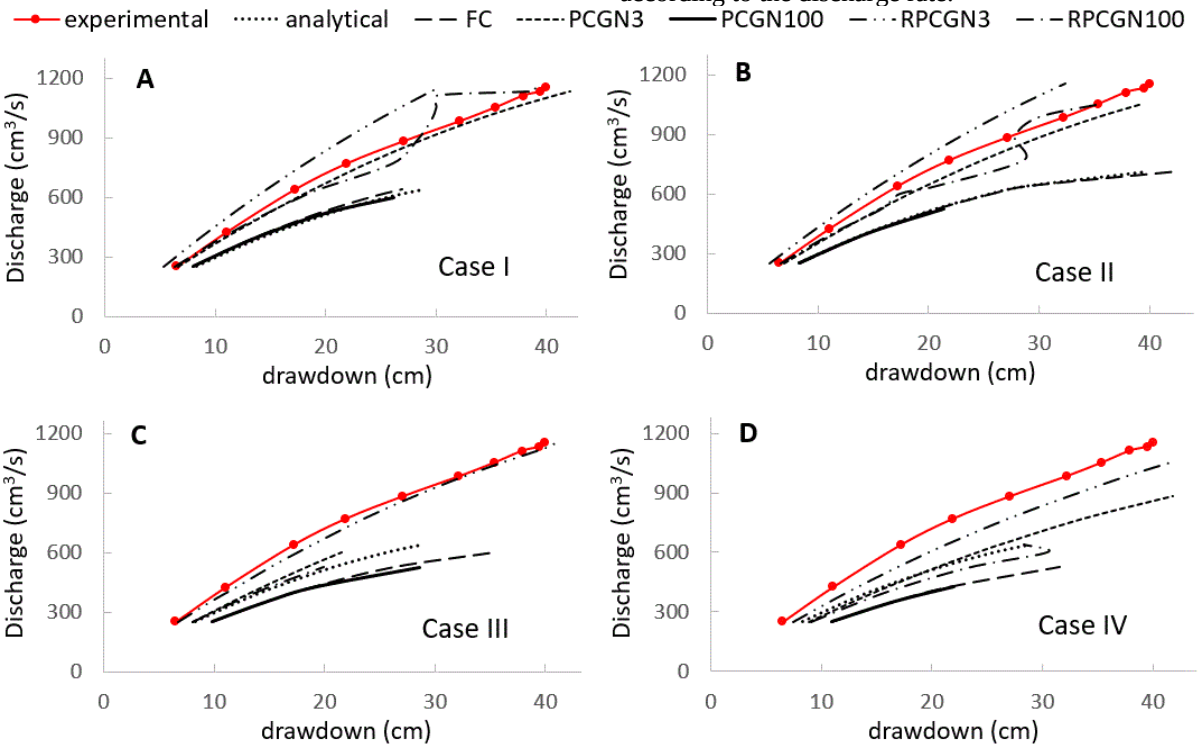


Fig. 6 *Discharge-drawdown relationships for well 1 in all four implemented global grids: a) case I; b) case II; c) case III; and d) case IV. Linear models were left out for clarity.*

Fig. 6 shows that, as the grids get finer in spacing, the solutions produce increasing drawdowns; this is consistent with all wells and numerical solutions. Therefore, if the solutions overestimate the drawdowns, the spacing should be increased, and if the solutions underestimate, with finer mesh the results become more consistent, as in RPCGNn (Table 5; Fig. 5b; Fig. 6).

Overall, methods are mesh-sensitive as for which gives better results and this also changes with well position. Almost without any exception, PCGNn provides the best results for coarser uniform grids and RPCGNn for the finer. Other techniques perform better with some wells than others. For *case I*, drawdowns in wells close to the center (Wells 4, 2, and 1) of the circular aquifer may be predicted using PCGN100, FC, and analytical and for wells far from the center using PCGN1, RPCGN1, RPCGN100, and RPCGNn. For *case III*, PCGN100 and FC (as in *case I*) provides good results at and around the center and diverges from the experimental when the wells are located within the outer half of the aquifer diameter; unlike *case I*, analytical solution will not follow them. In wells closer to the constant head boundary, RPCGN1 performs better as in *case I*; nonetheless, PCGN1 and RPCGN100 give less accurate results in *case III* when compared to *case I*. For *case IV*, too, PCGN100 provides small $RMSE$s for the center well and the RMSE increases gradually as the location of the eccentric wells lie near the boundary. The increase in error is also true for FC, which is grossly overestimating the drawdowns in Well 3 for the only two discharge rates, 428.57 and 618.57; it produces output that but not for the analytical. RPCGN1, on the other hand, does not have a consistent change in *case IV*; it is good for Wells 1 and 5.

Discussion and conclusions

The results of this study reveal that smaller drawdowns provide more consistent results for wells eccentrically located in a circular island unconfined aquifer. The degree of this consistency, however, differs among the models with refinement and discretization. With respect to mesh size, some methods perform better than others do for a certain mesh. PCGN solver with user controlled *iter_mo* adapts to finer grids if local refinements at and around the well are performed (RPCGNn); however, the explanation to this condition is not clear. Generally too-fine mesh is not considered due to its consumption of computer memory and computation time; studies such as in Rushton and Tomlinson (1977) gear towards using coarser grids permissible to obtain optimal results. Well eccentricity matters in terms of global grid selection: wells closer to the aquifer center are more likely to produce robust outputs.

Overall, there is no need for excessive refinement or fine discretization as long as a single well operates; thus, *case I* and *case II* adequately address the problem at hand. However, if for any reason, local refinement is needed, the global mesh must be finer for consistency. In conclusion, if the geometry of the model changes, the mesh sensitivity analysis should be conducted in order to choose the optimal grid.

Our data showed that, for most models, numerical results gradually deviate from experimental results as the eccentricity of the well in operation increases. This is only logical because, for example, the distance from the external circular boundary dwindles to 25 cm for Well 3, which, in turn, contradicts the Dupuit's assumption that the aquifer is infinite and because the large vertical flow components (for Well 3, a drawdown of 38.1 cm is obtained experimentally while 25 cm afar the drawdown is zero). This also confirms the results that, for smaller drawdowns, $RMSE$s are smaller because only in those cases do the theoretical and physical models become more in line with each other.

The discharge rate should not be any larger than when the oscillations in Fig. 3 start taking place in order for PCG2 (or PCGN100) to be used. For Well 4, for example, it should not go roughly beyond 570 cm^3/s after which large drawdown fluctuations occur before the convergence (for a smaller than experimental drawdown) takes place. The high $RMSE$s for the FC (and perhaps for PCGN100 (or PCG2)) emerge due to overestimation of drawdowns for these models, something expected because at high discharges the vertical gradients create seepage face, something the Dupuit assumptions preclude, and the assumption that no flow through the vadose zone takes place.

Picking an iter_mo that is not big enough for the PCGN solver to converge is a questionable step to take. One may also argue that for finer global grids the results do not reflect that of experimental if refinement is not applied. The response to that would lie in the fact that the used *iter_mo*s were calibrated under the coarser grids. Thus, knowing that *iter_mo* depends on eccentricity, and it adapts to the discretization, it is an innovative way to deal with the problem of overestimated drawdowns in converged cases (PCG2 and PCGN100). Therefore, it is suggested that, as long as there is large drawdown data to calibrate the model, working with non-converged models is acceptable, and, thereby, verifies that MODFLOW's PCGN solver may be used in circular island unconfined aquifers for eccentric wells as long as it is user-controlled. The same conclusion cannot be stated for PCG2 solver unless either the drawdowns or the eccentricity is small.

Another challenge in this study was regarding the drying cells. Through refinement of well itself, this was minimized, in that, while the head at some cells within the well dropped below the aquifer base, some still remained above, and when averaged, the drawdown remained above zero. Future studies may include changing the default parameters used in this study to examine how well the converged results perform.

The results of this study indicated that the PCGN solver performs well in drawdown estimation for eccentric wells in Circular Island unconfined aquifers under steady state condition provided that calibration data for high drawdowns is available. PCG2 and PCGN100 provide the same outputs for same grid systems. PCG2 and FC models' performance is limited to small drawdowns and small eccentricities, and they gradually diverge from the experimental when either of them becomes larger. Analytical model performs well for very small eccentricities. This is coherent with the fact that wells closest to the outer boundary perform better with PCGN1 (linear solution) and closer to the center with PCGN100, showing that less eccentricity means more nonlinearity. For single-well operating systems, models perform better using course grids.

However, the overlap of the analytical, FC, and PCGN100 results, and the obvious error in some of the experimental measurements (the unreasonable results

of Well 5) may lay a ground to replicate the experiments for a well-grounded conclusion. The findings in this study may be of practical uses in pump and treat systems designed to prevent contamination from spreading or remove contaminant mass in unconfined aquifers. This could be achieved by controlling the discharge rate and the drawdowns.

References:

1. Birpinar, M. E., & Gazioglu, S. A. (2002). Discharge-drawdown relationship of eccentric wells. *Journal of Hydrologic Engineering, 7*(3), 260-264.

2. Babbit, H., & Caldwell, D. (1948). The free surface around, and interface between, gravity wells. *Engineering Experiment Station.*

3. Boulton, N. S. (1951). The flow pattern near a gravity well in a uniform water-bearing medium.(includes appendices). *Journal of the Institution of Civil Engineers, 36*(10), 534-550.

4. Clement, T., Wise, W. R., Molz, F. J., & Wen, M. (1996). A comparison of modeling approaches for steady-state unconfined flow. *Journal of Hydrology, 181*(1), 189-209.

5. De Wiest, J. R. (1963). Flow to an eccentric well in a leaky circular aquifer with varied lateral replenishment. *Geofisica Pura E Applicata, 54*(1), 87-102.

6. Dupuit, J. (1863). *Etudes theoriques et pratiques sur le mouvement des eaux dans les canaux decouverts et a travers les terrains permeables avec des considerations relatives au regime des grandes eaux, au debouche a leur donner et a la marche des alluvions dans les rivieres a fond mobile* Dunod.

7. Hantush, M. S. (1964). Hydraulics of wells. *Advances in Hydroscience, 1*, 281-432.

8. Hantush, M. S., & Jacob, C. E. (1960). Flow to an eccentric well in a leaky circular aquifer. *Journal of Geophysical Research, 65*(10), 3425-3431.

9. Mishra, P. K., & Kuhlman, K. L. (2013). Unconfined aquifer flow theory: From dupuit to present. *Advances in hydrogeology* (pp. 185-202) Springer.

10. Muskat, M., & Wyckoff, R. D. (1937). Flow of homogeneous fluids through porous media.

11. Rushton, K. R. (2003). *Front matter* Wiley Online Library.

12. Rushton, K., & Tomlinson, L. (1977). Permissible mesh spacing in aquifer problems solved by finite differences. *Journal of Hydrology, 34*(1-2), 63-76.

13. Shamsai, A., & Narasimhan, T. (1991). A numerical investigation of free surface—Seepage face relationship under steady state flow conditions. *Water Resources Research, 27*(3), 409-421.

14. Siddiraju, S. (2013). Pumping test analysis of large diameter wells in pulang river basin cuddaph district. *International Journal of Innovative Research and Development|| ISSN 2278–0211, 2*(3), 129-136.

15. Verruijt, A. (1982). The finite element method. *Theory of groundwater flow* (pp. 105-121) Springer.

16. Wang, H. F., & Anderson, M. P. (1995). *Introduction to groundwater modeling: Finite difference and finite element methods* Academic Press.

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